TM 11-300

WAR DEPARTMENT TECHNICAL MANUAL

FREQUENCY METER SETS

SCR-211-A, B, C, D, E, F, J, K, L, M, N, O, P, Q, R, T

AA, AC, AE, AF, AG, AH, AJ, AK, AL

WAR DEPARTMENT • *JULY 1944*

WAR DEPARTMENT TECHNICAL MANUAL

TM 11-300

This manual supersedes TM 11-300, 19 December 1941; TM 11-300F, 26 February 1942; TM 11-300J, 30 June 1942; TM 11-300L, 11 May 1942; TM 11-300Q, 17 March 1943; TM 11-300T, 15 May 1943; TM 11-300AA, 28 June 1943; TM 11-300AC, 15 June 1943; TM 11-300AE, 7 August 1943; TM 11-300AF, 2 November 1943; TM 11-300AG, 9 December 1943 and 14 January 1944; TM 11-300AH, 20 December 1943; TM 11-300AJ, 26 November 1943; TM 11-300AL, 10 March 1944; and section I, Training Circular No. 4, War Department, 1943.

FREQUENCY METER SETS

SCR-211-A,B,C,D,E,F, J,K,L,M,N,O,P,Q,R,T.

AA,AC,AE,AF,AG,AH,AJ,AK,AL.

WAR DEPARTMENT *JULY 1944*

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[A.G. 300.7 (18 Mar 44).]

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IBn 1: T/O 1-27; 1-37; 1-47; 1-67; 1-117; 1-127; 1-137; 1-147; 1-267; 1-300-1; 1-317; 1-487S; 1-547; 1-618; 1-637; 1-638; 1-687S-6; 1-757; 1-758; 1-759; 1-767; 1-777S; 1-800-1; 1-977.

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IC 17: T/O 17-2; 17-12; 17-20-1; 17-22; 17-46S; 17-56; 17-60-1.

IC 18: T/O 18-26; 18-36.

IC 19: T/O 19-56; 19-57.

IC 44: T/O 44-1-3S; 44-10-1; 44-10-2S; 44-12; 44-26; 44-116; 44-126; 44-136; 44-147S; 44-226S; 44-312; 44-316.

For explanation of symbols see FM 21-6.

WARNING

WHEN BATTERIES ARE BEING LOADED INTO THE BATTERY COMPARTMENT, DO NOT TOUCH THE CONNECTING LEADS OR TERMINALS. A SEVERE SHOCK MAY RESULT. DO NOT SHORT-CIRCUIT THE TERMINALS OF THE TERMINAL BOARD WHILE MAKING CONNECTIONS.

WHEN USING THE FREQUENCY METER TO CALIBRATE A TRANSMITTER, NEVER MAKE ANY DIRECT CONNECTION BETWEEN THE METER AND THE TRANSMITTER.

DESTRUCTION NOTICE

WHY — To prevent the enemy from using or salvaging this equipment for his benefit.

WHEN—When ordered by your commander.

HOW — 1. Smash—Use sledges, axes, handaxes, pickaxes, hammers, crowbars, heavy tools, etc.

2. Cut—Use axes, handaxes, machetes, etc.

3. Burn—Use gasoline, kerosene, oil, flame throwers, incendiary grenades, etc.

4. Explosives—Use firearms, grenades, TNT, etc.

5. Disposal—Bury in slit trenches, fox holes, other holes. Throw in streams. Scatter.

USE ANYTHING IMMEDIATELY AVAILABLE FOR DESTRUCTION OF THIS EQUIPMENT

WHAT—1. Smash—Oscillator ceramic coil forms and all other parts on underside of chassis of frequency meter after removing chassis from cabinet by loosening holding screws on front panel.

2. Cut—As many wires and cables as time permits.

3. Bend and/or break—Calibration dial and knobs on front panel of frequency meter.

4. Burn—Calibration books, manuals, circuit label, and remainder of entire frequency meter.

5. Bury or scatter—Any or all of the above pieces after breaking.

DESTROY EVERYTHING

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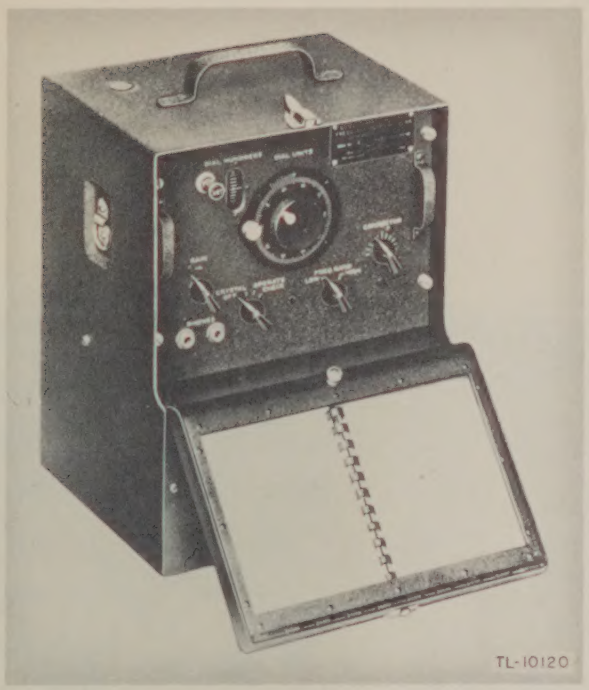

Figure 1. Frequency Meter BC–221–(&), in metal cabinet.

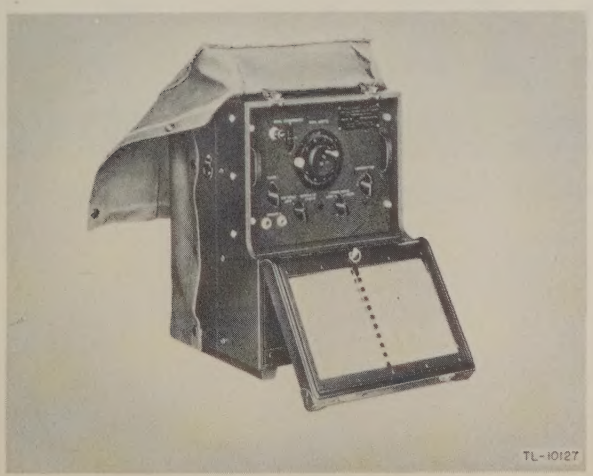

Figure 2. Frequency Meter BC–221–(&), in wooden cabinet.

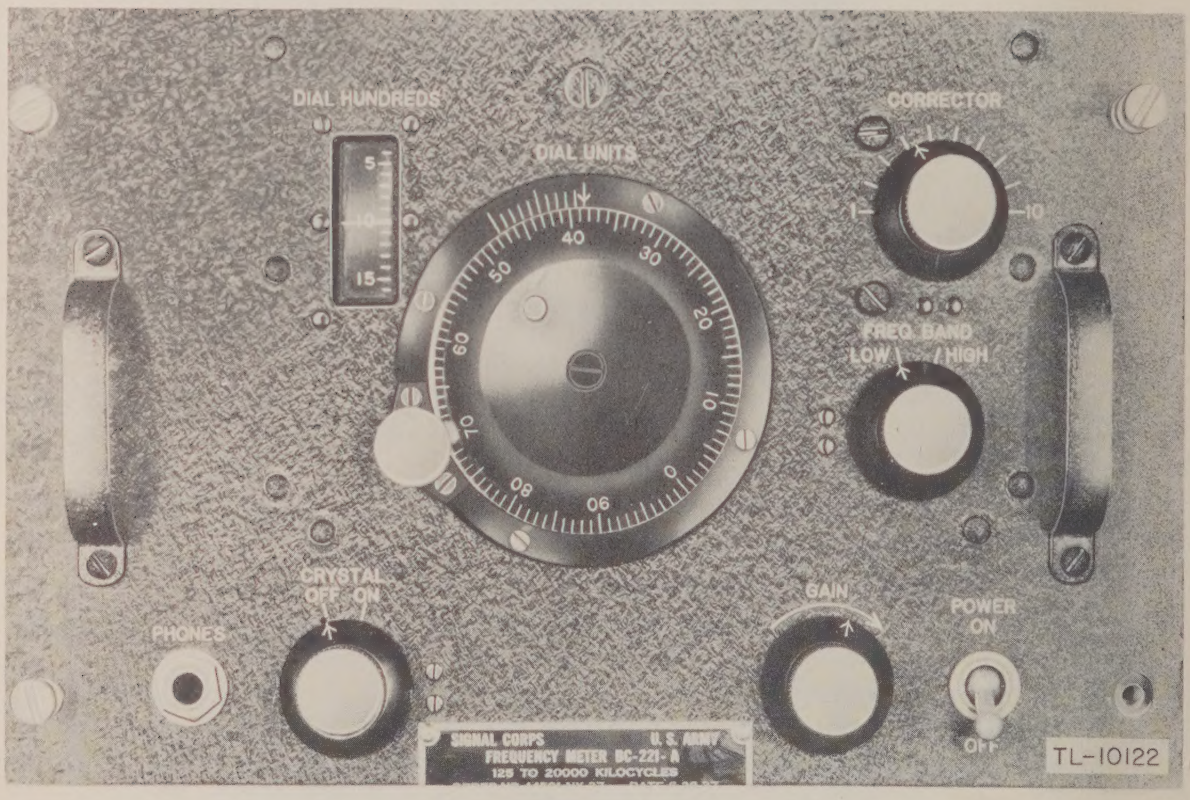

Figure 3. Frequency Meters BC–221–A, BC–221–C, and BC–221–D, control panel lay-out.

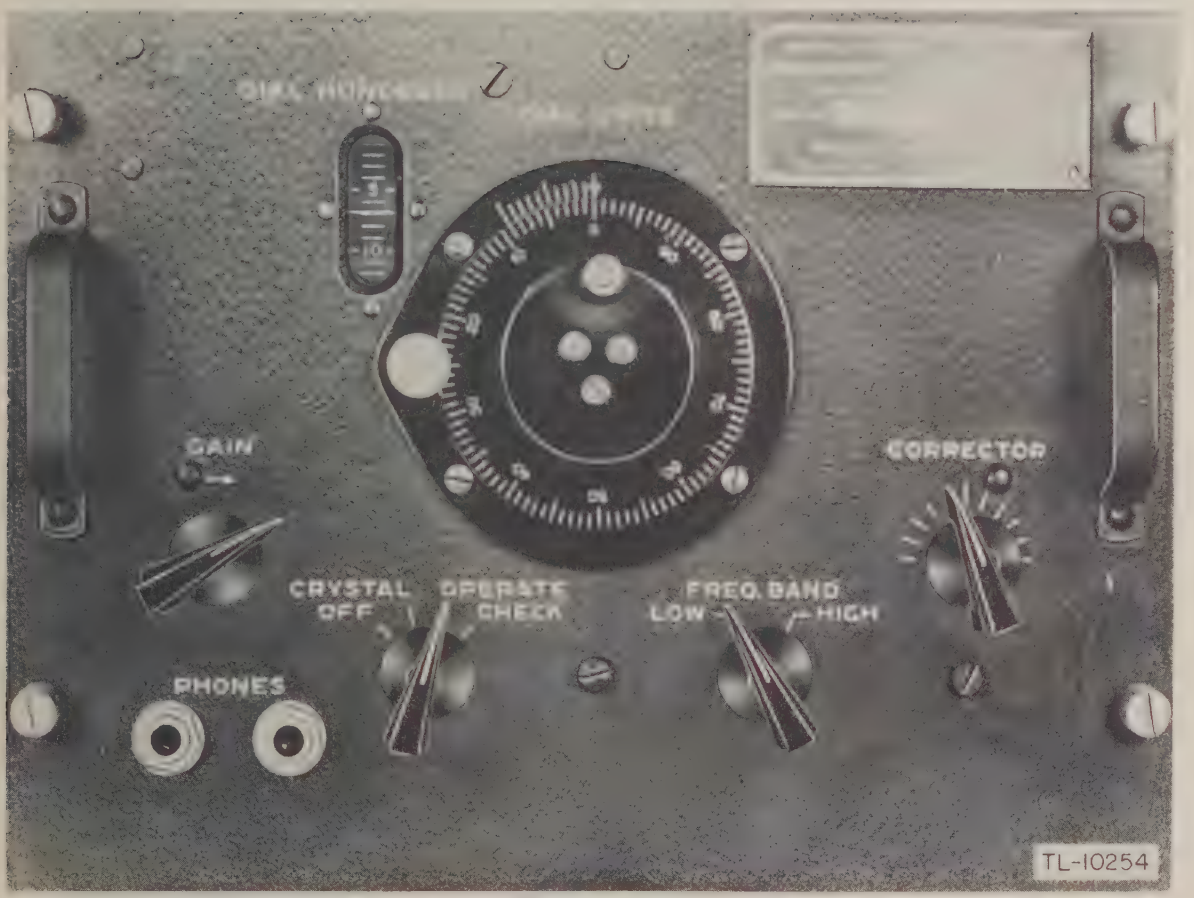

Figure 4. Frequency Meters BC–221–B, BC–221–E, BC–221–N, BC–221–Q, BC–221–AA, BC–221–AE, and BC–221–AG, control panel lay-out.

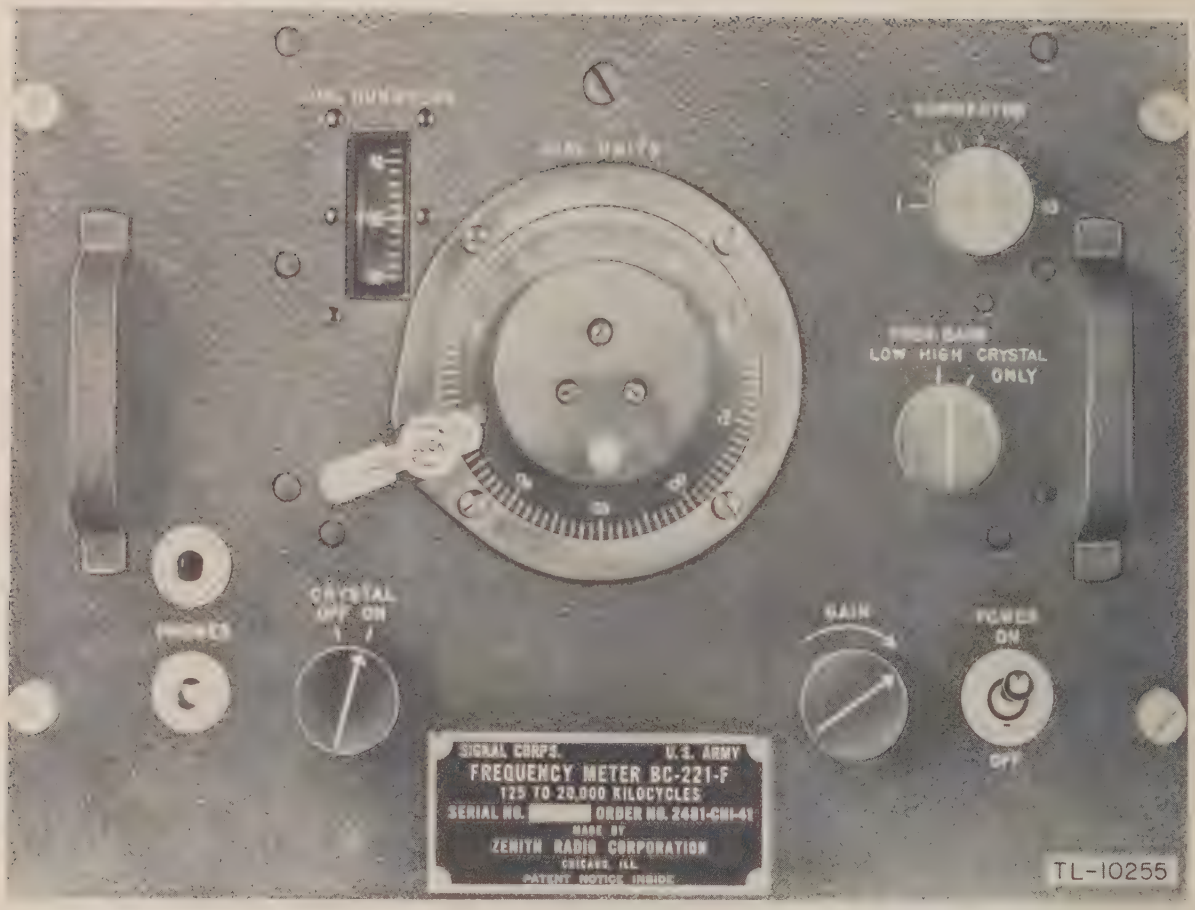

Figure 5. Frequency Meters BC–221–F, BC–221–J, BC–221–K, and BC–221–L, control panel lay-out.

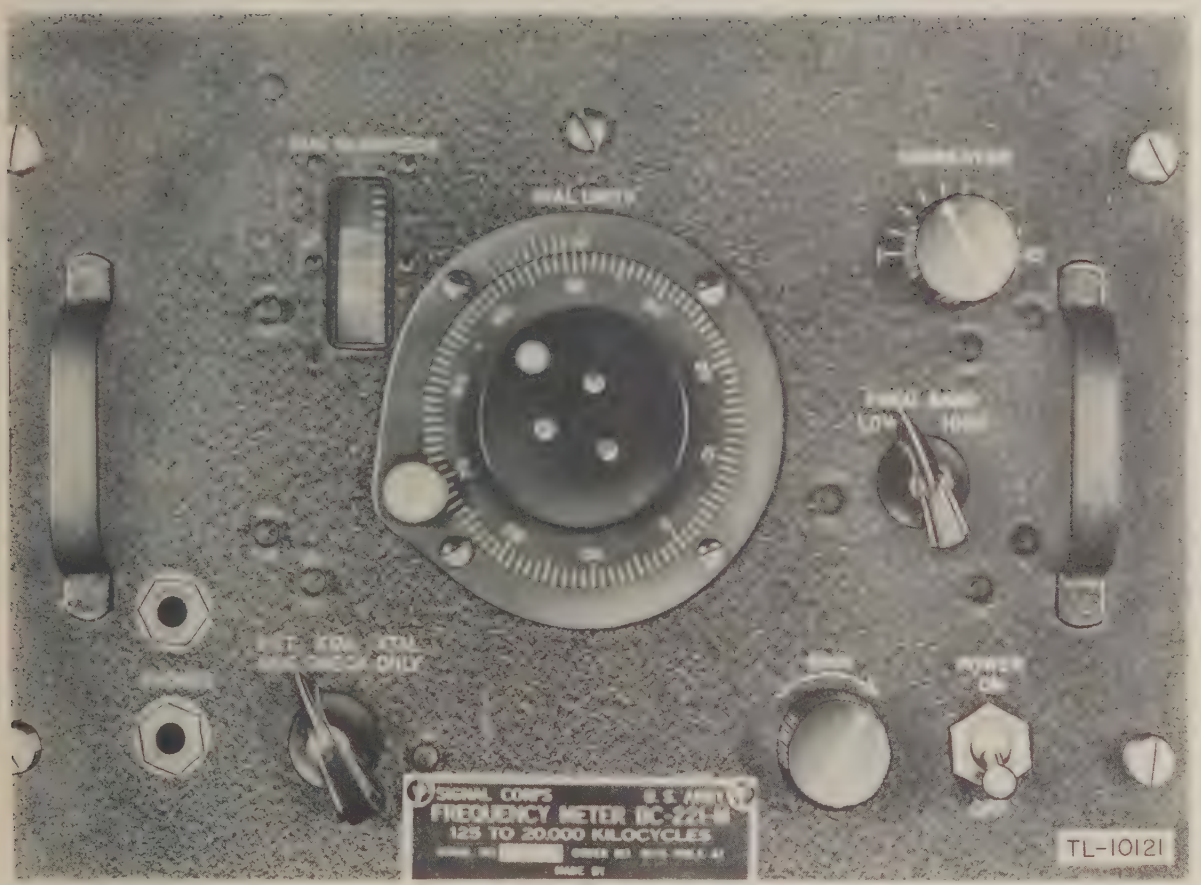

Figure 6. Frequency Meters BC–221–M, BC–221–O, BC–221–P, BC–221–R, BC–221–T, BC–221–AC, BC–221–AF, and BC–221–AH, control panel lay-out.

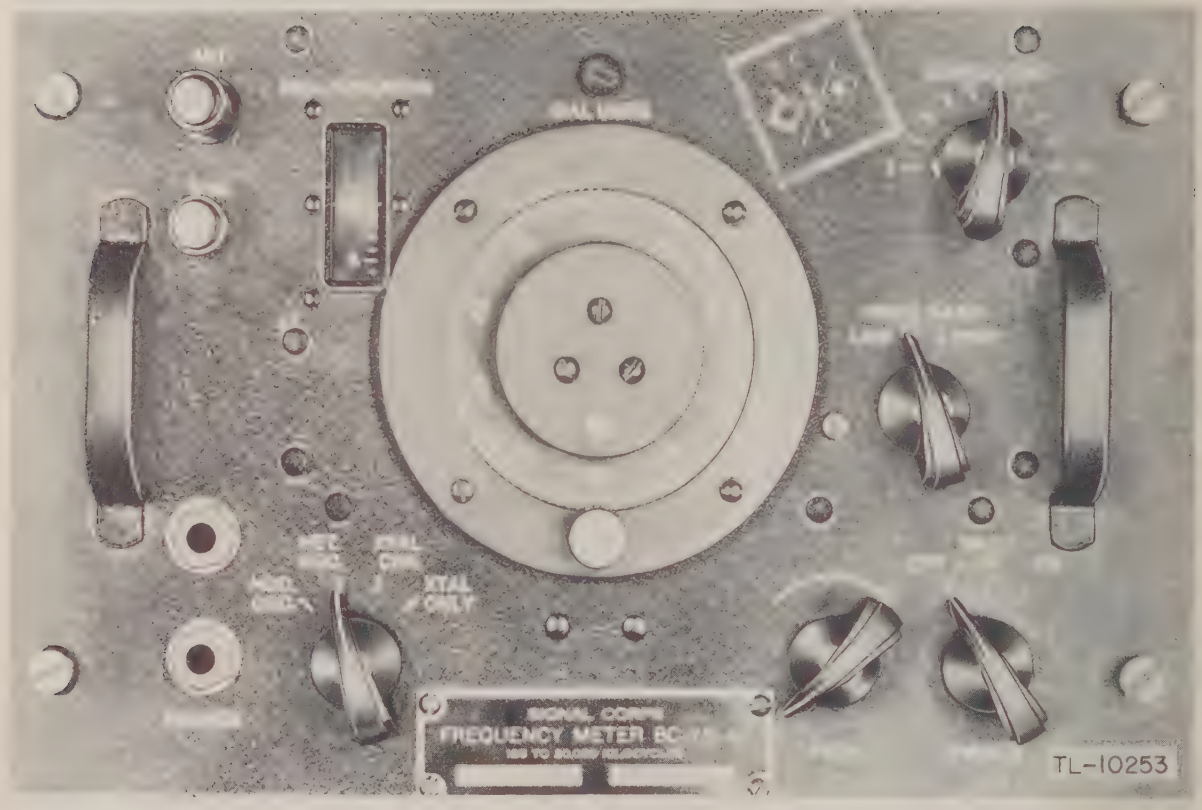

Figure 7. Frequency Meters BC–221–AJ and BC–221–AL, control panel lay-out.

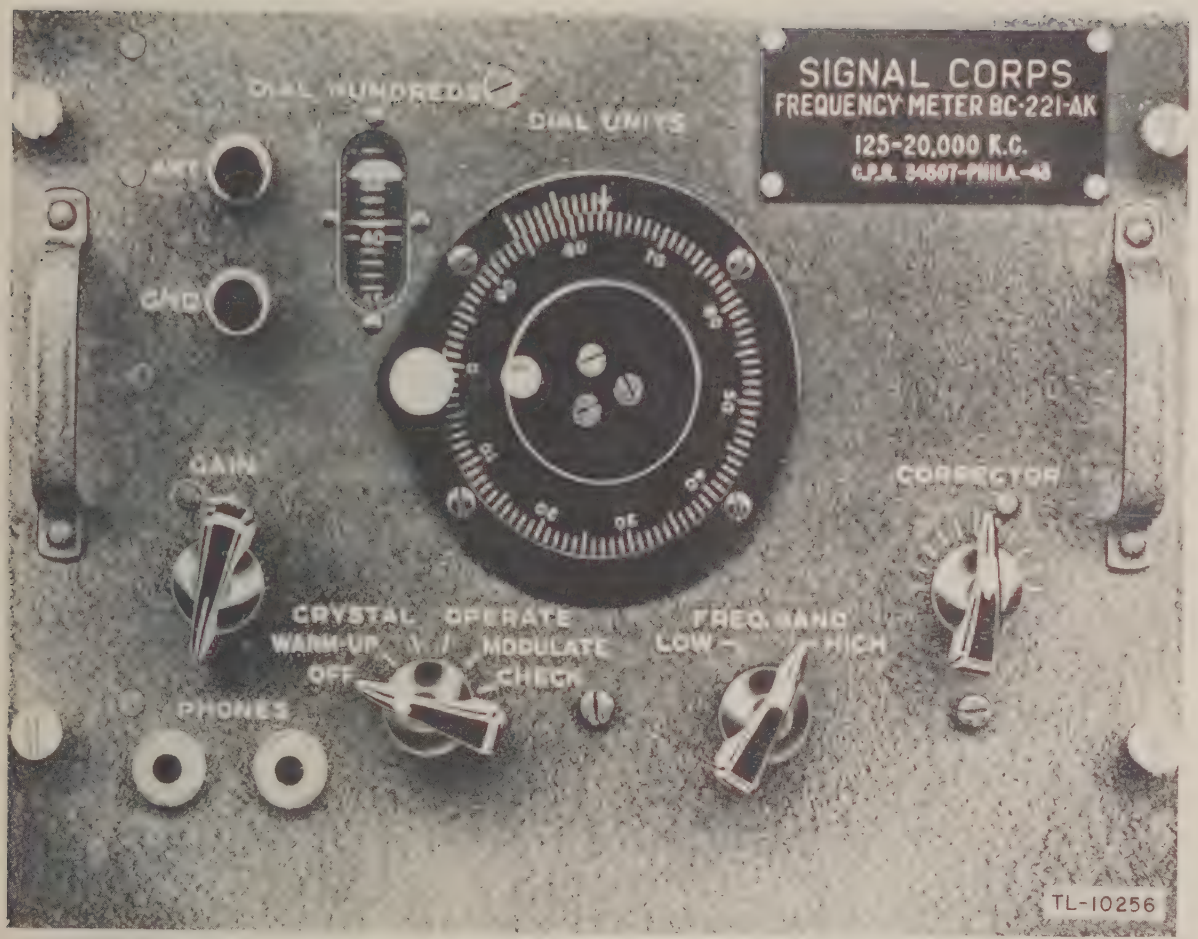

Figure 8. Frequency Meter BC–221–AK, control panel lay-out.

This manual supersedes TM 11-300, 19 December 1941, TM 11-300F, 26 February 1942, TM 11-300H, 30 June 1942, TM 11-300L, 11 May 1942, TM 11-300Q, 17 March 1943; TM 11-300T, 15 May 1943; TM 11-300AA, 28 June 1943; TM 11-300AC, 15 June 1943; TM 11-300AE, 7 August 1943; TM 11-300AF, 2 November 1943; TM 11-300AG, 9 December 1943 and 14 January 1944; TM 11-300AH, 20 December 1943; TM 11-300AJ, 26 November 1943; TM 11-300AL, 10 March 1944; and section I, Training Circular No. 7, War Department, 1943

CHAPTER 1

GENERAL INFORMATION AND INSTRUCTIONS

Section I. DESCRIPTION

1. Introduction

a. This manual is intended to give a detailed description of the operation and use of Frequency Meter Set SCR–211–(&). The models covered are as follows: SCR–211–A, –B, –C, –D, –E, –F, –J, –K, –L, –M, –N, –O, –P, –Q, –R, –T, –AA, –AC, –AE, –AF, –AG, –AH, –AJ, –AK, and –AL. Each model letter denotes a different order, in most cases, and very often a different manufacturer. All of these models are similar as far as basic operation is concerned, but there are many differences in the mechanical arrangement of the cabinets and controls as well as in electrical circuit and vacuum tube arrangements.

b. Chapter 1 contains information and instructions which are applicable to all the frequency meter sets described in later chapters. It contains a detailed description of these frequency meter sets and their use, and a general description of the component parts and their circuits.

c. The remaining chapters describe the detailed functioning of the component parts and other necessary information for each frequency meter set. Where two or more models are almost identical, they are covered in the same chapter with an explanation of all differences between them.

d. As additional models of the frequency meter set are made, the special information pertaining to these new models will be issued in the form of supplements which will be made a part of this manual. Before using any particular model, read this chapter. Then read the chapter pertaining to the model that is going to be used, making all cross-references to other chapters as noted specifically in the text.

e. The symbol (&) as used throughout this manual applies to all models of Frequency Meter Set SCR–211. Similarly, the symbol (&) applies to all models of Frequency Meter BC–221. For an explanation of all other suffix symbols used in this manual refer to the following chart:

Symbol	Refers specifically to—	Chapter covering equipment
(&)	All models of Headset HS–30	1 through 11
(1)	Models A, C, and D of Frequency Meter Set SCR–211 or its components	2
(2)	Models B and Q of Frequency Meter Set SCR–211 or its components	3
E	Model E of Frequency Meter Set SCR–211 or its components	4
(3)	Models F, J, K, and L of Frequency Meter Set SCR–211 or its components	5
(4)	Models M, O, R, and AC of Frequency Meter Set SCR–211 and its components	6
(5)	Models N and AA of Frequency Meter Set SCR–211 and its components	7

Symbol	Refers specifically to	Chapter covering equipment
(6).....	Models P, T, AF, and AH of Frequency Meter Set SCR–211 or its components.....	8
(7).....	Models AE and AG of Frequency Meter Set SCR–211 or its components.....	9
AK.....	Model AK of Frequency Meter Set SCR–211 or its components.....	10
(8).....	Models AJ and AL of Frequency Meter Set SCR–211 or its components.....	11

2. General

a. The Frequency Meter Set SCR–211–(&) is a precision instrument designed to measure or radiate radio-frequency impulses between 125 and 20,000 kilocycles (kc). It is a portable, completely self-contained instrument used mainly to calibrate field radio receivers and transmitters by direct comparison with the calibrated variable frequency oscillator of the frequency meter. Each meter contains a 1,000-kc crystal-oscillator circuit which is used both as a source of accurate radio-frequency signals at multiples of 1,000 kc, and for calibrating the variable frequency oscillator of the instrument at a number of points. These points of frequency calibration are called "Crystal Check Points."

b. The principal component of the set is Frequency Meter BC–221–(&), a heterodyne-type frequency meter, which is supplied in either of two types of cabinet: a black wrinkle-finished aluminum-alloy cabinet (fig. 1), or an olive-drab finished wooden cabinet. (See fig. 2.) The upper and largest compartment of the cabinet contains the frequency meter chassis and sometimes some of the spare parts. The next smaller compartment, at the bottom rear, contains the batteries. The smallest compartment, at the bottom front, contains either spare parts or the headset. (See figs. 19, 20, 21, and 25 for representative views.) A carrying handle and one or two snap latches are mounted on the top surface of the cabinet. Two small rings to which carrying Strap ST–19–A can be hooked, are mounted at the sides of the cabinet. The BC–221–Q, BC–221–AA, BC–221–AC, BC–221–AE, BC–221–AF, BC–221–AG, BC–221–AH, BC–221–AJ, BC–221–AK, and BC–221–AL frequency meters are normally supplied with the wooden cabinet. Some BC–221–Q and BC–221–AA frequency meters come with the aluminum-alloy cabinet. All other models are supplied with the aluminum-alloy cabinet.

c. Frequency Meter BC–221–(&) is calibrated in two ranges: 125 to 250 kc, and 2,000 to 4,000 kc. By the use of the 2d, 4th, and 8th harmonics of the low-frequency range, any frequency between 250 and 2,000 kc can be obtained; by the use of the 2d, 4th, and 5th harmonics of the high-frequency range, any frequency between 4,000 and 20,000 kc can be obtained. The crystal oscillator has a fundamental frequency of 1,000 kc. Its fundamental and harmonic frequencies are used to check the calibration of the variable frequency oscillator at a large number of points.

d. The various models of Frequency Meter BC–221–(&) come with six different types of control panel arrangement. Some of these arrangements are further modified in the location of the antenna post, ANT, and sometimes a ground post, GND, mounted on the control panel instead of on top of the cabinet. These modifications are shown on the figures of the particular models. (See figs. 3 through 8, incl.)

NOTES. 1. In addition to the controls shown on figure 4, the control panel of the BC–221–AA and BC–221–AE contains an antenna post, ANT, and the control panel of the BC–221–AG contains both an ANT and GND post.

2. In addition to the controls shown on figure 6, the control panel of the BC–221–AC, BC–221–AF, and BC–221–AH contains both an ANT and GND post.

e. A careful study of these panel lay-outs will indicate that there are certain controls which are the same in all models of Frequency Meter BC–221–(&). These are: DIAL HUNDREDS, DIAL UNITS, CORRECTOR, GAIN, and PHONES. The function of these items is the same in all cases. Some models contain a POWER ON-OFF switch while in other models this function is combined with other switching

operations. All models have a FREQ. BAND LOW-HIGH switch. In the case of figure 5, it will be seen that a third function, CRYSTAL ONLY, is combined with this switch. The greatest difference between the various models lies in the switch which controls the operation of the crystal oscsillator. This switch is called the operation switch throughout this manual. In figures 3 and 5, it is marked CRYSTAL OFF-ON; in figure 4, it is marked OFF-CRYSTAL-OPERATE-CHECK; in figure 8, OFF-WARM-UP-CRYSTAL-OPERATE-MODULATE-CHECK; in figure 6, HET. OSC-XTAL CHECK-XTAL ONLY; and in figure 7, MOD. OSC.–HET. OSC-XTAL CHK-XTAL ONLY. The use of these controls will be described in detail in the chapter on each particular model.

3. Frequency Setting Error

Frequency Meter Set SCR–211–(&) is a reliable frequency measuring instrument, but it is subject to certain errors, a condition common to all such equipment.

a. The greatest possible error in frequency setting of the frequency meter occurs at a setting of 4,000 kc (and its harmonics) when the temperature is —30° C. Most frequent causes of error are as follows:

Cause	*Error*
(1) Small shocks (caused by handling, and the thrust on the dial and pressure on the panel when using the equipment)	100 cycles maximum
(2) The action of locking the dial	30 cycles maximum
(3) Warming up	100 cycles maximum
(4) Changing of load on the antenna post	50 cycles maximum
(5) A drop of 10 percent in battery voltage or a change of 5° centigrade, in the surrounding temperature	325 cycles maximum
(6) Error in calibration	500 cycles maximum
(7) Error in crystal frequency	250 cycles maximum
Total	1,355 cycles maximum or 0.034% at 4,000 kc.

b. This is the theoretical maximum error. It should be noted that even normal handling of the instrument, such as manipulation of the controls, locking the dial, etc., may cause errors as shown in the table. Also, variation in the value of the battery supply voltage, antenna load, calibration, as well as deviations in crystal frequency and during warm-up of the tubes, may cause errors. In actual operation, however, the errors listed will not necessarily add together, as some may cancel others. For example, locking the dial and changing the antenna load may not result in an error totaling exactly 80 cycles. Actual tests show that, in most cases, the average error can be assumed to be no greater than 50 percent of the values given in the table. Maximum possible errors at other frequencies are: 985 cycles at 2,000 kc; 180 cycles at 250 kc; and 180 cycles at 125 kc.

4. Components

A complete listing of the various components normally furnished with each model of Frequency Meter Set SCR–211–(&) cannot be made because of differences in contractual requirements of the various manufacturers as well as variations in policy of issue of the supply depots. Each Frequency Meter Set SCR–211–(&) must be equipped with the following component parts before it is ready for use:

Quantity	Component
1	Frequency Meter BC–221–(&) includes: 1 Calibration Book MC–177–(&). 1 Crystal Unit DC–9–(&) (in operating position).
1	Set of vacuum tubes in place (applicable types).
1	Set of batteries (installed) includes: 6 Batteries BA–2. 4 Batteries BA–23.
1	Headset and cord (applicable types).

In addition to the above items necessary for operation (all not necessarily furnished with the set), some models come supplied with various spare parts: carrying straps, bags, tools, etc. In order to avoid confusion, those extra items normally supplied with the equipment are listed in detail under that portion of this manual applying to a particular model or series of models.

5. Replaceable Parts

Replaceable parts and components are dependent upon the model of Frequency Meter Set SCR–211–(&). Therefore, separate replaceable parts lists have been made up for each different model and will be found in the appropriate chapter. For models in which some parts have been changed during production, the difference in parts is noted and explained.

6. Power Consumption

All power required for the operation of Frequency Meter Set SCR–211–(&) is supplied by the batteries listed in paragraph 4. Because of the different types of tubes used and differences in circuit arrangements, the power supply current drain of the various models may differ. For this reason, the power drain of each model or series of models will be described in the chapter on the model in question.

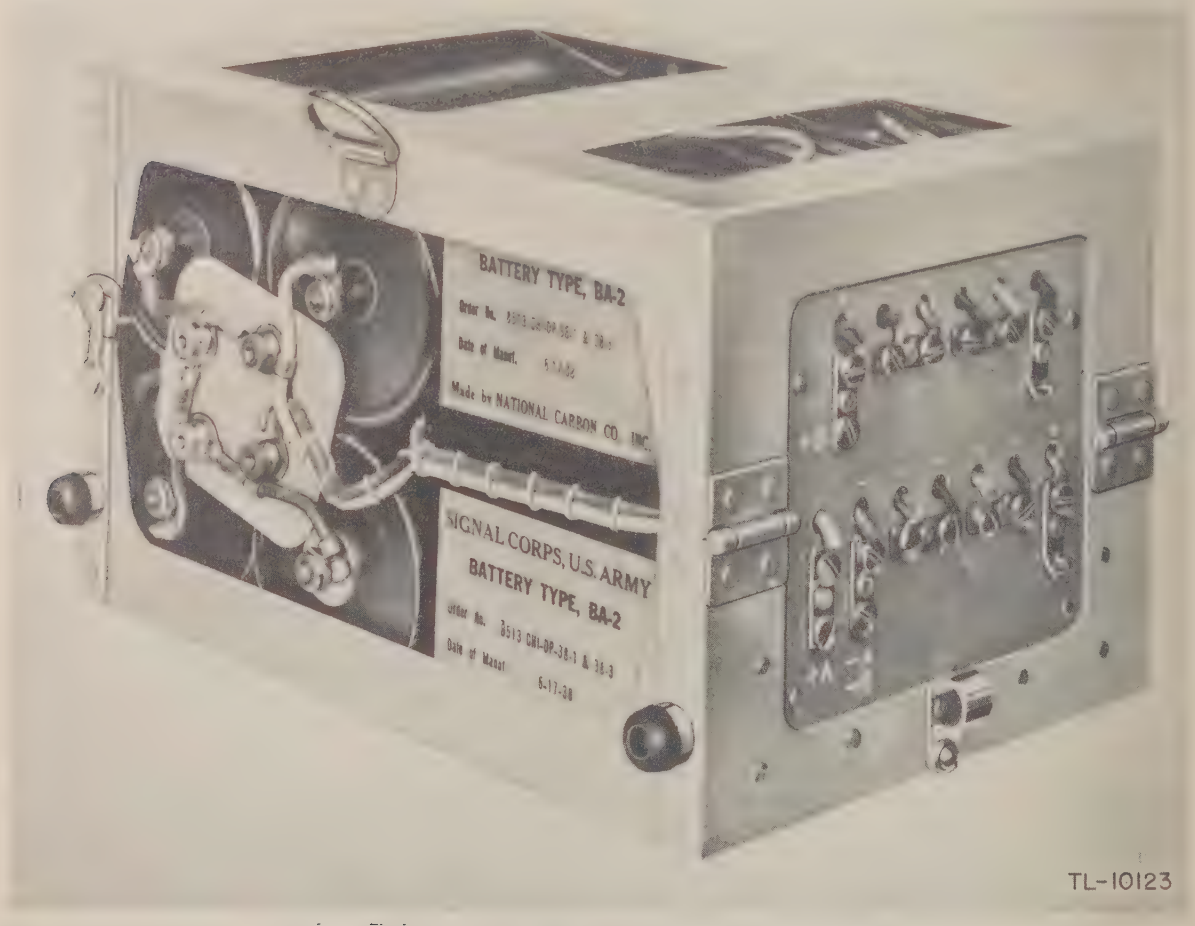

Figure 9. Frequency Meters BC–221–B, BC–221–Q, battery tray.

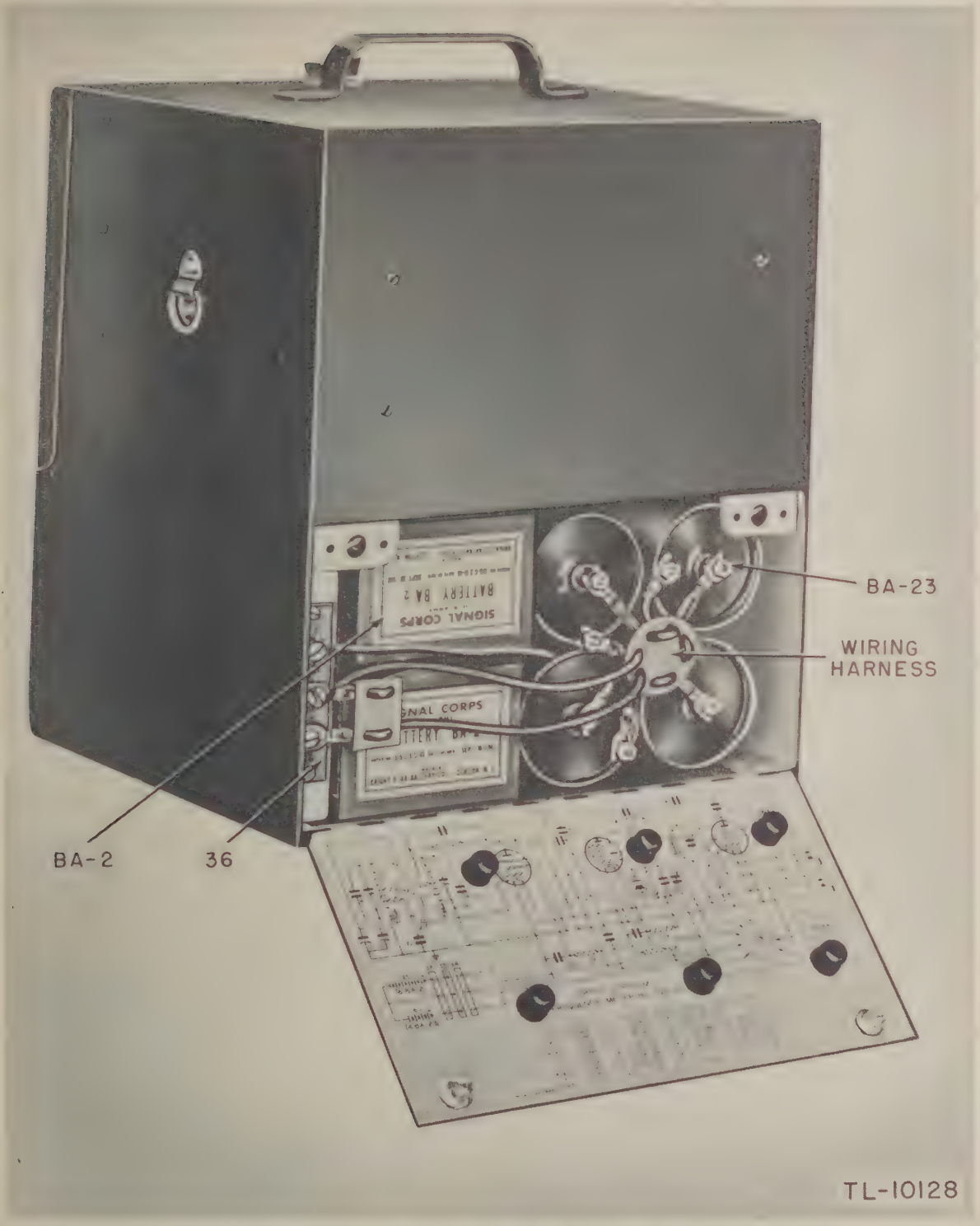

Figure 10. Use of wiring harness with battery installation, in metal cabinet.

Section II.

INSTALLATION AND OPERATION

7. Initial Procedure

Unpack Frequency Meter Set SCR–211–(&) with care, remove the instrument from its protective canvas bag or cover, and thoroughly inspect all compartments of the frequency meter cabinet for possible damage during shipment. Check all components against the listing in the chapter on the model in question to see that all necessary components for the particular model have been issued. See that the vacuum tubes and the crystal unit are seated properly in the correct sockets.

8. Installation of Batteries

a. GENERAL. Frequency Meter BC–221–(&) obtains all of its operating voltages from batteries. These are not ordinarily included when

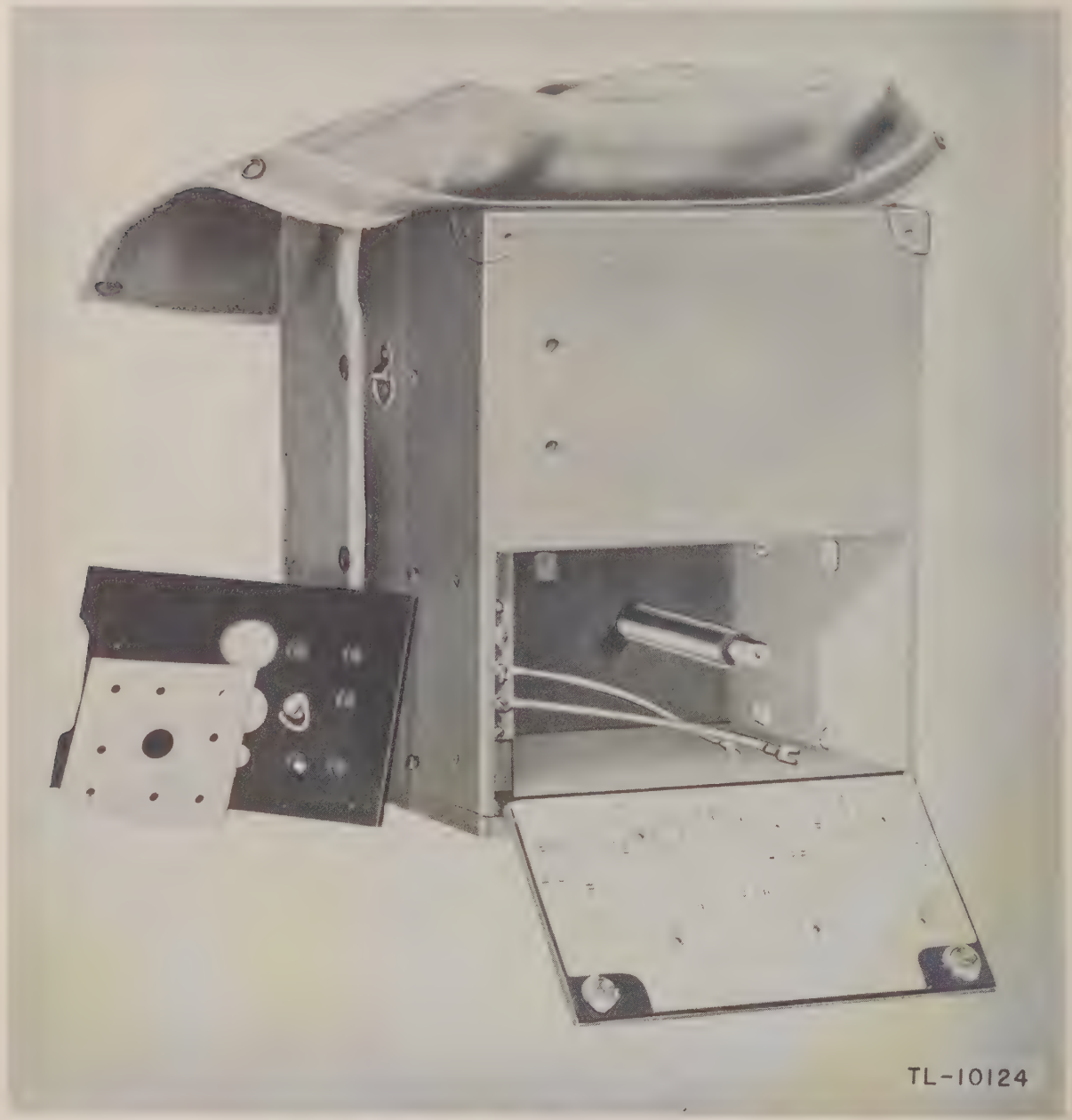

Figure 11. Battery compartment, wooden cabinet, showing fiber connecting board and A battery leads.

shipment is made, since batteries may deteriorate and cause damage to the interior of the equipment. Before the instrument can be operated, however, four *A* Batteries BA–23, and six *B* Batteries BA–2 must be installed. Select these batteries from fresh stock whenever possible.

b. Types of Battery Installation. There are three different types of battery installation used in the various models of Frequency Meter Set SCR–211–(&). These are as follows:

(1) The use of a battery tray or chassis as supplied with Frequency Meters BC–221–B and BC–221–Q. (See fig. 9.)

(2) The use of a battery clamp and wiring harness as supplied with all metal cabinet models with the exception of those listed in (1) above. Supplied with Frequency Meters BC–221–A, BC–221–C, BC–221–D, BC–221–E, BC–221–F, BC–221–J, BC–221–K, BC–221–L, BC–221–M, BC–221–N, BC–221–O, BC–221–P, BC–221–R, BC–221–T, and BC–221–AA (with metal cabinet). (See fig. 10.)

(3) The use of a fiber connecting board together with a wiring harness and battery retaining board as supplied with all wooden cabinet models with the exception of Frequency Meter BC–221–Q, b (1) above. These items are supplied with BC–221–AA (with wooden case), BC–221–AC, BC–221–AE, BC–221–AF, BC–221–AG, BC–221–AH, BC–221–AJ, BC–221–AK, and BC–221–AL. (See fig. 11.)

c. Battery Connection. In all models of Frequency Meter BC–221–(&), the series connection of the *A* battery is taken care of automatically by proper installation of the wiring harness. There are two methods of making the proper arrangement of the *B* batteries.

(1) When the battery tray or chassis is used (fig. 9), connect the six Batteries BA–2 individually to the proper screws on the terminal board at the end of the tray, which is so arranged as to connect the individual batteries in series. This method applies to the BC–221–B and BC–221–Q, only.

(2) For all other models, connect the six Batteries BA–2 in series before installation in the cabinet, and cover the splices with friction tape or spaghetti in order to avoid short circuits. (See fig. 12.)

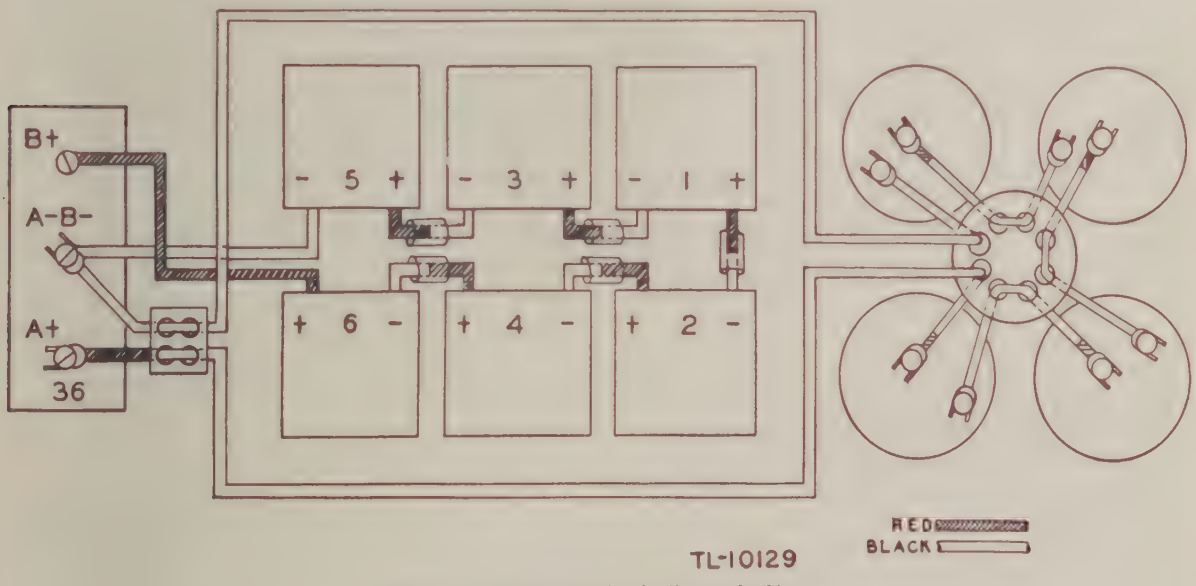

Figure 12. Battery connection details, metal cabinet.

d. Testing Batteries. The most satisfactory methods of testing dry cell batteries is to test them under full load conditions in the equipment with which they are to be used. Make a load voltage test with a thousand-ohm-per-volt voltmeter after new batteries are installed, or if the ones installed previously are suspected of having low voltage output. Turn on the BC–221–(&). With the controls set so that the meter is working under full-load conditions (described under "Power Consumption" in the chapter on the model being tested), check the voltage of the batteries at the connection board in the

battery compartment. The correct readings obtained under these conditions should be as follows:

Terminals	Normal d=c Voltage	Minimum d=c Voltage
A–B–to A+	6.0	5.4
A–B–to B+	135.0	121.5

If the voltages obtained are less than the minimum values, replace the batteries. If a sufficient number are available, always replace with a complete set of fresh batteries.

9. Antenna

a. In order that the frequency meter may pick up an adequate signal from a transmitter being checked, or radiate an adequate signal to a receiver being calibrated, some form of antenna is required on the frequency meter. Where the meter is to be used in fixed service or is carried about over small distances, a rigid antenna is most convenient. One to two feet of No. 12 copper wire is usually quite satisfactory. Fasten this wire to the antenna post on the frequency meter and bend it so that its free end will run parallel, and close to the antenna lead of the receiver or transmitter being checked. Adjust the amount of coupling by moving the frequency meter or bending the antenna wire, or wrap a few turns of insulated wire around the frequency meter antenna and connect one end of this wire to the receiver being checked.

Caution: Never connect the frequency meter antenna directly to transmitter. Important operating circuits of the frequency meter may be burned out by the high r-f voltage present and make the meter unfit for further use.

b. Where conditions do not permit the use of a rigid antenna, use a flexible insulated wire of suitable length with means provided to prevent its becoming a safety hazard. Remove the insulation from one end of the wire and fasten this end to the antenna post. If a test clip is available, a very convenient coupling device can be made by first dulling the sharp edges of the jaws of the clip, then insulating each jaw with friction tape. Attach this clip to the other end of the wire. By means of this insulated clip, it is possible to couple the frequency meter to almost any desired coupling point without actually making contact.

Caution: Always attach the antenna to the frequency meter before correcting the calibration of the meter with the crystal oscillator. This will eliminate the effect of the frequency shift caused by attachment of the antenna.

10. Headset

The various models of the Frequency Meter Set SCR–211–(&) make use of different headsets. Some of the earlier models use Headset P–18 or P–20, whereas the later models use Headset HS–30–(&) and Cord CD–605. Some models have space provided within the frequency meter cabinet for storage of the headset, while in others, the headset is carried in the top portion of the protective cover. In any model, it is necessary that the headset be plugged into the PHONES jack before the meter will operate, because the filament circuit of the vacuum tubes is controlled by a set of springs on the PHONES jack. In some cases where only one headset is available and two are needed, such as during the calibration of a receiver, it is possible to energize the filament circuit of the meter by inserting a pencil or similar object of the proper size into the PHONES jack. *If this procedure is used, extreme care should be exercised to avoid damage to the jack.*

11. Reading the Dial

a. GENERAL. Before attempting to turn the main tuning dial (DIAL UNITS), always make sure the dial lock is loosened. The drum-dial behind the small window (fig. 13) indicates, in hundreds, the reading of the dial setting. The large dial provides the units, and the vernier scale, above and on the outside edge of the large dial, provides the tenths place of the setting. The large dial is provided with the simple friction lock so that a predetermined setting can be kept fixed. This feature is of particular value when the instrument is subjected to vibration.

b. USE OF THE DIAL. (1) *Setting the dial.* To set this control, having loosened the locking screw:

(*a*) Turn the dial until the proper hundred graduation is directly under the line marked on the window.

(*b*) Turn the dial clockwise until the proper

whole unit graduation on the dial is directly opposite the fixed arrow.

(*c*) Beginning with the next higher graduation on the dial as 1, count in a counterclockwise direction a number of graduations equal to the number of tenths in the decimal, count the same number of graduations on the vernier, then turn the dial clockwise until the last graduation counted on the dial coincides exactly with the last graduation counted on the vernier.

(*d*) Figure 13 is an illustration of the dial setting 3876.7.

Caution: Always approach the final setting of the dial by turning it in a clockwise direction to eliminate errors caused by backlash in the gears of the dial mechanism.

(2) *Reading the dial.* To read the vernier, find that line of the vernier scale which coincides most closely with a line of the large dial. The number of this vernier line (counting the index arrow as zero), gives the tenths place of the complete dial setting. On the large dial the line to the right of the index arrow gives the value of the units place of the complete dial setting, while the line directly above the line in the small window to the left of the large dial gives the hundreds value. Before using the frequency meter for actual measurements, it is a good idea to practice on the dial until settings can be made and read off quickly and accurately.

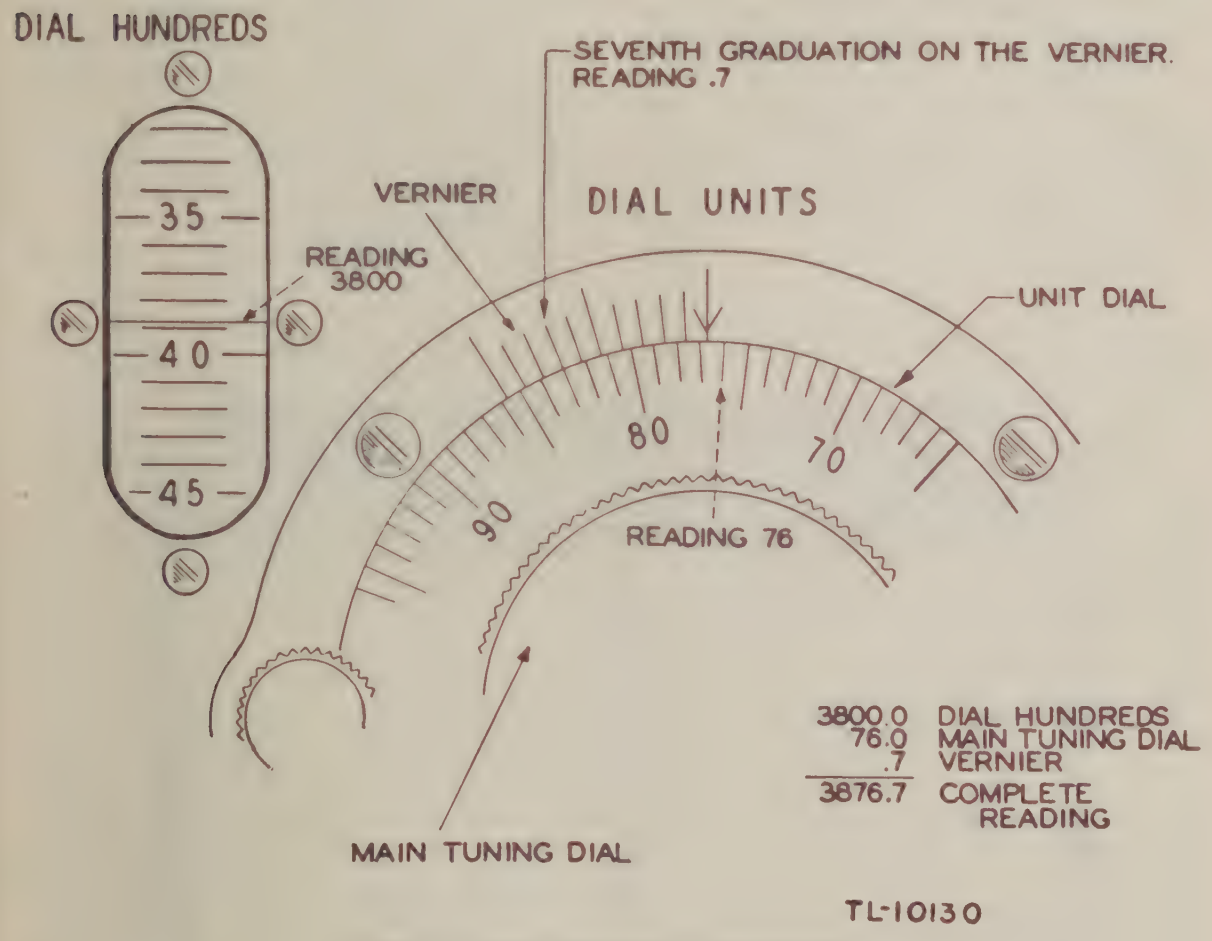

Figure 13. Frequency Meter BC-221-(&), main tuning dial.

12. Calibration Book MC–177–(&)

The calibration book is kept in the front cover of the meter chassis compartment. When the cover is opened to expose the control panel of the meter, it swings down to a position which permits ready reference to the contents of the book. In the early models of the BC–221–(&) (type letters A through AF), a transparent shield is supplied to protect the book, and can be pulled open readily for turning the pages. In the later models (type letters AG and up), a solid metal cover is supplied. The calibration books supplied with the various models may differ slightly as far as internal arrangements are concerned, but all contain essentially the same information. Any exceptions to this general rule are noted below.

a. Function. The calibration book is a list of dial settings and the corresponding frequencies produced by the meter at those dial settings. Altogether 1,251 dial-frequency settings spaced 100 cycles apart have been determined in the LOW frequency range, and 2,001 settings spaced 1,000 cycles apart have been determined in the HIGH frequency range. Inasmuch as the variable frequency oscillator circuit of the meter produces more than one frequency at a given setting (fundamental and harmonic frequencies), several of the harmonics produced are given at each dial setting. The book also contains concise operating instructions for making common measurements.

Note. The values listed in the calibration section refer only to the meter whose serial number is printed on the fly leaf. The calibration book must be protected. It is a valuable tool, a very important part of the equipment, and takes a great deal of time to duplicate.

b. Indexing (fig. 14). (1) Each section of the calibration book is cross-indexed in the fol-

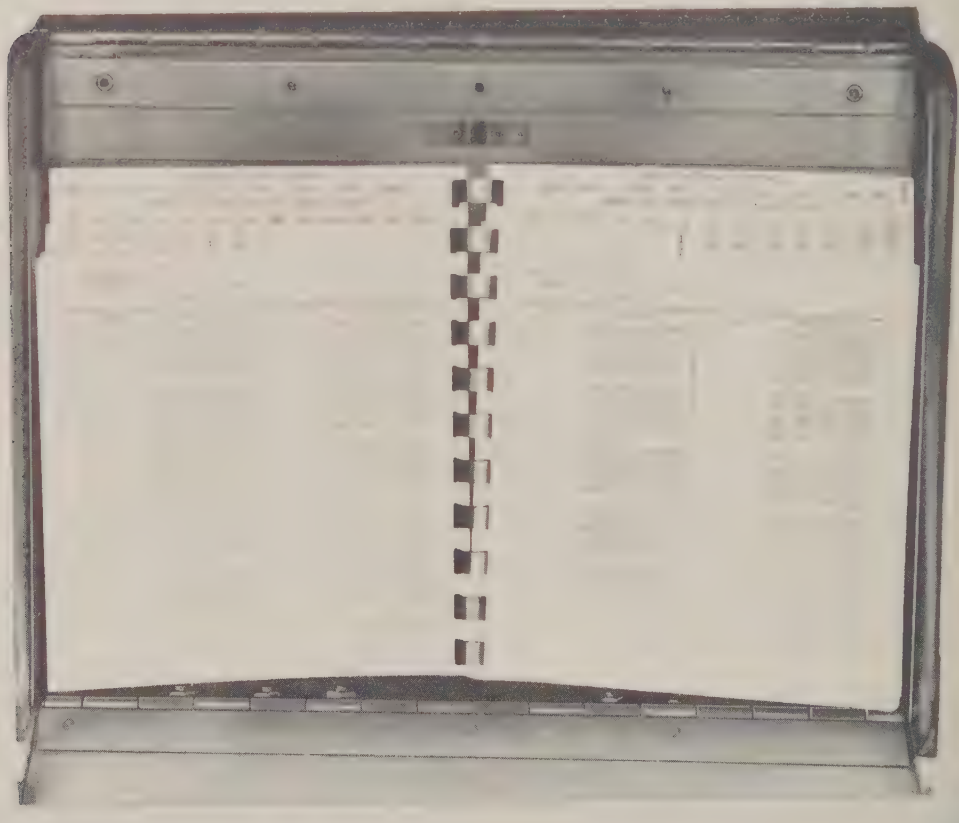

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Figure 14. Calibration Book MC–177–(&).

lowing way: across the top of the large pages in either section of the book, is an INDEX OF DIAL SETTINGS (called GUIDE TO DIAL SETTINGS in some books), spaced 500 divisions apart. Beneath each dial setting of this guide is the tab containing the number of the page on which that setting is found. For example, note that the edge of the tab marked "16" falls between the figures 2500 and 3000. Then note that the dial readings on page 16 in the figure run from 2577.5 to 2756.3, in the range of 2500 to 3000. Immediately under this INDEX OF DIAL SETTINGS is found an INDEX OF FREQUENCIES—KILOCYCLES (called "Guide to frequencies" in some books) listing columns of frequencies in both ranges. The tab of the page on which those frequencies are found, is located directly under the appropriate column. For example, note that tab 16 is directly under the figure 190 and that the right edge of tab 17 leaves all of the 190 column exposed. The figures thus exposed are the frequencies contained in the first line and the first column of the FREQUENCY RANGE on page 16. (Note that the indexing described above was omitted in the book included with the BC 221–A.)

(2) In addition to the tubular index described above, general indexes of the calibration ranges and an INDEX OF FREQUENCIES AT CRYSTAL CHECK POINTS are found at the center of the book.

(3) The red figures, at the bottom of each page, opposite the CRYSTAL CHECK POINT dial setting, list the frequencies emitted by the variable frequency oscillator when tuned to *zero beat* at that crystal point.

(4) Some calibration books have the AVERAGE NUMBER OF DIAL DIVISIONS PER KILOCYCLE for that page listed at the bottom of the right-hand column on each page. This practice has been discontinued on the later models.

c. Finding a Dial Reading for a Given Frequency. (1) Open the calibration book to the INDEX OF FREQUENCIES found on the long, center page and find the number of the page on which the desired frequency is to be found; or use the convenient INDEX OF FREQUENCIES printed at the top of the long pages, b (1) above which enables the operator to open the book to the proper page by the use of the thumb tab desired.

(2) After the page has been found, examine the appropriate column of frequencies to locate the desired frequency. In the left-hand column, on the same line, the correpsonding dial reading will be found.

d. Finding the Frequency from a Given Dial Reading. (1) Open the calibration book to the long center page. From the INDEX TO LOW FREQUENCY DIAL SETTINGS preceding the center page, or the INDEX TO HIGH FREQUENCY DIAL SETTINGS following the center page, determine the number of the page on which the desired dial reading appears; or use the convenient INDEX OF DIAL SETTINGS printed at the top of the long pages, b (1) above, which enables the operator to open the book at the proper page by the use of the thumb tab.

(2) After the page has been found, examine the left-hand column to locate the dial setting nearest the desired value. Move along the same line to the appropriate column of frequencies, and the frequency corresponding to a given dial setting may be read with generally satisfactory accuracy. When greatest accuracy is required, and the dial reading obtained in the measurement falls between dial readings listed in the book, exact interpolations, as described below, should be made.

e. Determining Intermediate Values Between Listed Frequencies. The desired frequency (when the frequency meter is being used to calibrate a radio transmitter), or the observed dial setting (when the frequency meter is being used to measure an unknown frequency) may often fall between the value listed in the calibration book. To aid in the calculation of the proper dial setting or the frequency corresponding to these intermediate values, the following method (called interpolation) should be used.

(1) *Given:* The observed dial setting is 2754.2. (See fig. 14.) This setting lies between the two successive book values 2756.3 and 2752.7. The corresponding frequencies for these book values are 195.0 and 194.9 kc (fundamental), respectively.

Problem: To find the unlisted frequency corresponding to a dial setting of 2754.2.

Solution: The facts are stated numerically in the following form:

Dial settings		*Corresponding frequencies kc*	
	2756.3		195.0
Diff. 3.6	2754.2	Diff. 1.5	*F*	Diff. 0.1 kc
	2752.7		194.9

F = Unknown frequency.

(*a*) 0.1 kc ÷ 3.6 div. = 0.0277 kc per dial division.

(*b*) 0.0277 kc x 1.5 div. = 0.0415 kc change from lowest calibration frequency to F.

(*c*) 194.9 kc + 0.0415 kc change = 194.9415 kc = F.

In the above problem, a change of 3.6 dial divisions (from 2752.7 to 2756.3) causes a change of 0.1 kc in frequency (from 194.9 to 195.0 kc). This represents a change of 0.0277 kc per dial division, (*a*) above. Since there are only 1.5 dial divisions between 2752.7 and 2754.2, the difference in frequency between these settings will equal 0.0277 kc x 1.5 div, (*b*) above. This difference (0.0415 kc) is then added to the lower known frequency (194.9 kc) at the dial setting of 2752.7, (*c*) above to give the unknown frequency F.

(2) *Given:* It is desired to set the frequency meter to a frequency of 194.95 kc. This frequency lies between the two successive book values 195.0 and 194.9 kc.

Problem: To find the dial setting which corresponds to the frequency 194.95 kc.

Solution: The facts are stated numerically in the following form:

Dial settings		*Corresponding frequencies kc*	
Diff. 3.6	2756.3	195.00	Diff. 0.1 kc
	D	194.95	
	2752.7	194.9	

Diff 0.05 kc

D = Unknown dial setting.

(*a*) 3.6 div. ÷ 0.1 kc = 36 dial divisions per kc.

(*b*) 36 div. x 0.05 kc = 1.8 dial divisions—change from lowest dial reading to D.

(*c*) 2752.7 + 1.8 = 2754.5, the dial setting D for a frequency of 194.95 kc.

In the above problem, changing the dial setting from 2752.7 to 2756.3 (3.6 dial divisions) causes a change of 0.1 kc in frequency (from 194.9 kc to 195.0 kc). This represents a change of 36 dial divisions per kc, (*a*) above. An increase in frequency from 194.9 kc to 194.95 kc is a change of 0.05 kc. Since a change of 36 dial divisions causes a change of 1.0 kc in the frequency, an increase of 0.05 kc requires a change of 36 div. x 0.05 kc equal 1.8 dial divisions, (*b*) above. This increase (1.8 div.) is then added to the dial reading (2752.7) corresponding to the lower known frequency (194.9 kc), to obtain the dial setting D corresponding to a frequency of 194.95 kc, (*c*) above.

(3) The methods demonstrated above are accurate for all frequency columns (harmonics) in the calibration book.

13. Operating Circuits

The frequency meter has four principal operating parts: a variable frequency oscillator, which is a source of radio waves of adjustable frequency and is controlled by the main tuning dial; a crystal oscillator circuit, which enables the operator to check the frequencies emitted by the variable frequency oscillator circuit; a detector or mixer circuit, which detects the difference of the frequencies of the preceding two oscillator circuits after combining the two frequencies electronically; and an audio-amplifying circuit which amplifies the difference or beat frequencies produced in the detector or mixer circuit when impulses from the crystal oscillator, or from an outside source (applied to the ANT post), encounter impulses from the variable frequency oscillator.

14. Zero Beat Detection

When two frequencies are present in the input of a detector or mixer circuit, the difference between the two will appear in the output circuit as a third frequency. This difference is called the beat frequency. If the two original frequencies are very close to the same value, the difference may be only a few thousand cycles or less. Such a low frequency lies within the audible range, and can be heard in the headset as a definite tone. This region of beat frequencies is shown schematically in figure 15. Starting at point (A) on the figure, a very high pitched note can be heard in the headset. As the two frequencies are brought closer to the same value (decreasing difference), the tone decreases in pitch down to point (B) where the tone is replaced by a series of rapid clicks. As the process continues still further, the clicks decrease in rapidity until they stop altogether at point (C). This is the point of *zero beat* (where the two original frequencies are exactly the same, that is, their difference value is zero). Matching of the two frequencies, for all practical purposes, is obtained when clicks are heard at rather infrequent intervals. It is extremely difficult to maintain a condition of absolute silence in the headset over prolonged intervals of time. If one of the two original frequencies is varied still further, the rapidity of the clicks increases to point (D). At this point a low pitched tone is heard. Further variation in the same direction

causes a gradual increase in pitch until point (E) is reached where the beat note becomes inaudible again. This region of increasing pitch on both sides of the zero beat point is characteristic of this procedure. (See par. 15b.) The frequency-mixing circuit of the frequency meter and its associated amplifier are designed to amplify tones of a few cycles per second. When the incoming signal is fairly strong, the clicks are sharp and distinct. If the signal is weak, the zero beat condition is evidenced by a slowly changing *swish* in the headset.

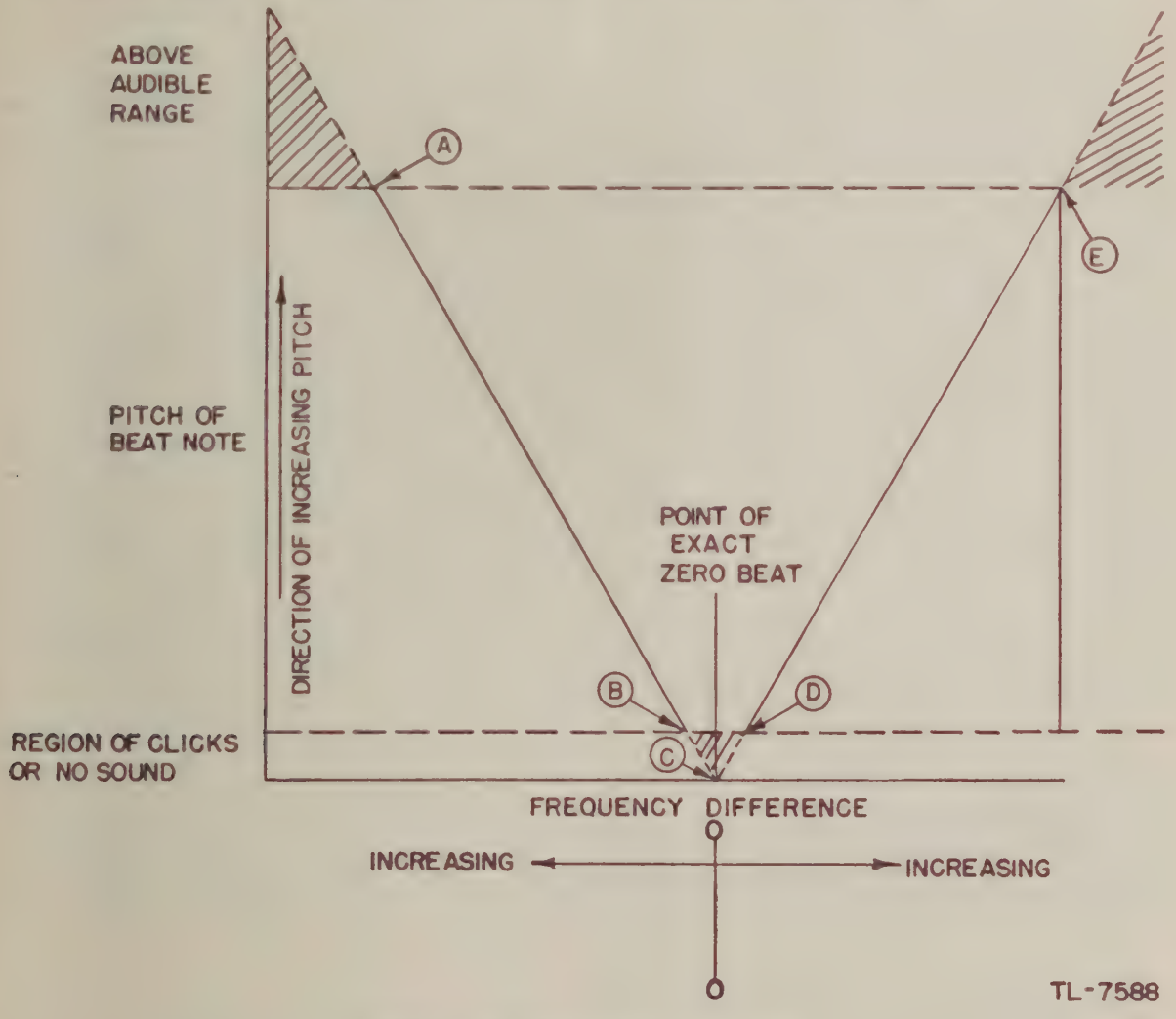


Figure 15. Beat frequency diagram, zero beat region.

15. Correction in Calibration

a. General. Before making a correction in the calibration of the meter, or using it for measurements, the meter should be turned on and allowed to warm up for 15 to 20 minutes to permit the operating temperature inside of the cabinet to become stable. Figure 7 shows that Frequency Meters BC–221–AJ and BC–221–AL have a WARM UP position on their power switches. Figure 8 shows that Frequency Meter BC–221–AK has a WARM UP position on its operation switch. When the proper switch is in the WARM UP position, the filament of the variable frequency oscillator tube only is connected to the *A* battery circuit. This results in a considerable saving of *A* battery power while permitting the interior of the meter to warm up to proper operating temperatures.

b. Calibration at CRYSTAL CHECK POINTS. By calibrating and correcting at a crystal check point, the meter is so adjusted that the frequency generated by the variable frequency oscillator at a given dial setting is ac-

tually the same as the frequency listed opposite the dial setting in the calibration book. This is accomplished by matching the output frequency (or a harmonic) of the variable frequency oscillator with a known fundamental (or harmonic) frequency of the crystal oscillator. A great many harmonic frequencies generated by the crystal oscillator circuit have been recorded and assigned definite positions on the main tuning dial. These are called CRYSTAL CHECK POINTS. Figure 16 shows a typical tuning curve of the BC–221–(&), together with CRYSTAL CHECK POINTS. Whenever the frequency of the variable frequency oscillator becomes equal to one of those frequencies, at the time of calibration, no sound should be heard in the headset. On either side of this matching position, however, a definite tone will be heard as either the tuning dial or the CORRECTOR control is turned, increasing in pitch until it vanishes completely. The operator using the equipment must exercise extreme care not to mistake this point of no sound for the true zero beat point which can always be identified by the increase in pitch on either side. Figure 17 is a block diagram which shows the adjustment of the variable frequency oscillator to a CRYSTAL CHECK POINT. It is desired to check the variable frequency oscillator at 3,000 kc, for example. After the meter has been warmed up, the tuning dial set according to the calibration book for 3,000 kc, and the crystal oscillator circuit put in operation, a beat note of 300 cycles is heard in the headset. This would indicate that the 3rd harmonic of the crystal oscillator (3,000 kc) is beating with the output frequency of the variable frequency oscillator in such a manner as to produce a difference frequency of 300 cycles. Since the crystal oscillator is known to be accurate, it is evident that the variable frequency oscillator is off calibration. Simple arithmetic will indicate that a variable frequency oscillator output frequency of either 2,999.7 kc or 3,000.3 kc would produce a difference of 300 cycles. Proper adjustment of the CORRECTOR control will bring the variable frequency oscilla-

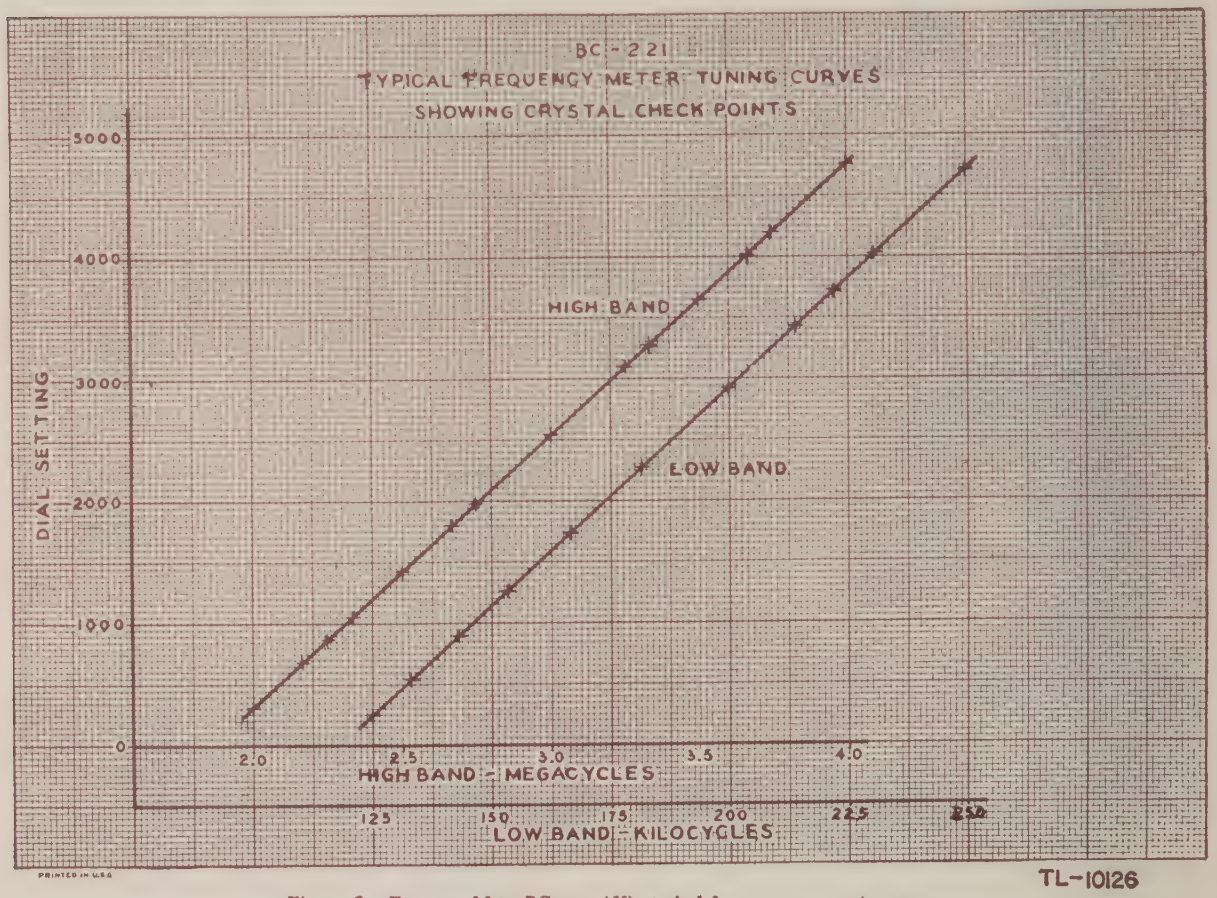


Figure 16. Frequency Meter BC–221–(&), typical frequency meter tuning curves.

tor output to the correct frequency of exactly 3,000 kc, when zero beat is obtained.

c. Typical Correction Procedure. The various models of the Frequency Meter BC–221–(&) use several different methods of making the correction setting because of variations in the marking of controls, and differences in circuit arrangements. The following procedure, on the BC–221–AA, is typical for the majority of models. (For details regarding other models, see the chapter on the specific model involved.)

(1) Determine whether the frequency at which the meter is to be calibrated lies in the LOW or the HIGH band. Turn the FREQ. BAND selector switch to the proper position.

(2) Open the panel cover which holds the calibration book. Using the index as described in paragraph 12b, locate the page on which the desired frequency is to be found. At the bottom of the page, the dial setting of the nearest crystal check point is found in the dial column opposite the designation CRYSTAL CHECK POINT which is printed in red.

(3) Turn the operation switch to CHECK. Both the crystal and variable frequency oscillator circuits are now in operation.

(4) Set the main tuning dial at the selected CRYSTAL CHECK POINT. A beat tone should be heard. If not, its absence will be due to one of the following possible conditions:

(*a*) The meter is exactly on calibration. If this is the case, then a slight change in *either* direction in the setting of the CORRECTOR control will produce a sound of increasing pitch in the headset.

(*b*) The two frequencies are so far apart that no sound is heard, that is, their beat frequency is out of the audible range. A change of the CORRECTOR control in the proper direction will produce an audible sound.

(*c*) The set is defective. In this case no sound will be heard at any point within the range of the CORRECTOR control.

(5) Assuming that a beat tone has been heard, move the CORRECTOR control knob in the direction of decreasing pitch until no sound is heard. This zero beat position of the CORRECTOR control knob must not be disturbed unless an entirely new crystal check point is to be used.

(6) After setting the main tuning dial to a CRYSTAL CHECK POINT as described above, check the accuracy of the frequency meter still further by rotating the main tuning dial to the next higher audible CRYSTAL CHECK POINT and noting the new dial reading. The difference between this dial reading and that listed on the next higher CRYSTAL CHECK POINT in the calibration book should be within 1.8 dial divisions on the LOW frequency band and 1.2 dial divisions on the HIGH frequency band. If this is not the case, always check the battery voltages before turning in the meter for repair.

(7) Turn the operation switch back to OPERATE. The calibration is now completed. The main tuning dial may now be turned to select any frequency covered by the crystal check

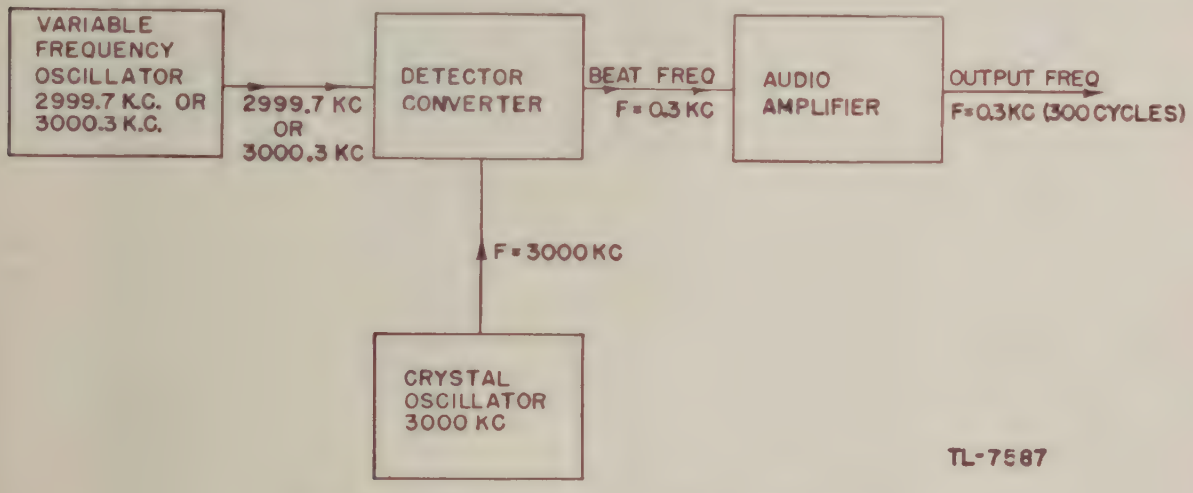

VARIABLE FREQUENCY OSCILLATOR 2999.7 K.C. OR 3000.3 K.C.
2999.7 KC OR 3000.3 KC
DETECTOR CONVERTER
BEAT FREQ F = 0.3 KC
AUDIO AMPLIFIER
OUTPUT FREQ F=0.3KC (300 CYCLES)
F = 3000 KC
CRYSTAL OSCILLATOR 3000 KC
TL-7587

Figure 17. Block diagram, correction at a CRYSTAL CHECK POINT.

Note. Switching from low to high band, switching from check to crystal or vice versa, or operating any of the controls, may cause the detector grid to block and the instrument to stop operating. If this happens, turn the instrument off and then on again.

point used, and the instrument dial settings will give the proper frequencies.

16. Crystal Check Points

Accumulated errors due to temperature, humidity, and battery voltage variations, and to rough handling can be corrected at a number of places along the tuning range of the instrument. This can be done by means of the beat notes between the fundamental frequency (or harmonics) of the variable frequency oscillator and the fundamental frequency (or harmonics) of the crystal oscillator. Since the harmonics of both oscillators are present in an unbroken series decreasing in strength as the order of the harmonic increases, and since any harmonic of one oscillator beating with any harmonic of the other can produce a beat note, there is considerable variation in the strength of the beat notes as the dial is turned across the tuning range. For convenience and accuracy, the relatively strong beat notes are chosen as CRYSTAL CHECK POINTS (with a very few exceptions). To avoid confusion as to the actual CRYSTAL CHECK POINTS, the lowest harmonic combinations of the two oscillator frequencies which will produce zero beat (CRYSTAL CHECK POINTS) are given in the following tabulation

Variable frequency oscillator fundamental frequency	X	Lowest variable frequency oscillator harmonic	=	Crystal oscillator fundamental frequency	X	Lowest crystal oscillator harmonic
125.00 kc	X	8	=	1,000 kc	X	1
133.33 kc	X	15	=	1,000 kc	X	2
142.86 kc	X	7	=	1,000 kc	X	1
153.85 kc	X	13	=	1,000 kc	X	2
167.67 kc	X	6	=	1,000 kc	X	1
181.82 kc	X	11	=	1,000 kc	X	2
200.00 kc	X	5	=	1,000 kc	X	1
214.29 kc	X	14	=	1,000 kc	X	3
222.22 kc	X	9	=	1,000 kc	X	2
230.77 kc	X	13	=	1,000 kc	X	3
250.00 kc	X	4	=	1,000 kc	X	1
2,000.00 kc	X	1	=	1,000 kc	X	2
2,166.7 kc	X	6	=	1,000 kc	X	13
2,250.0 kc	X	4	=	1,000 kc	X	9
2,333.3 kc	X	3	=	1,000 kc	X	7
2,500.0 kc	X	2	=	1,000 kc	X	5
2,666.7 kc	X	3	=	1,000 kc	X	8
2,750.0 kc	X	4	=	1,000 kc	X	11
3,000.0 kc	X	1	=	1,000 kc	X	3
3,250.0 kc	X	4	=	1,000 kc	X	13
3,333.3 kc	X	3	=	1,000 kc	X	10
3,500.0 kc	X	2	=	1,000 kc	X	7
3,666.7 kc	X	3	=	1,000 kc	X	11
3,750.0 kc	X	4	=	1,000 kc	X	15
4,000.0 kc	X	1	=	1,000 kc	X	4

NOTE. Many other combinations of frequencies of the variable frequency oscillator and the crystal oscillator will produce beat points which would confuse the operator except for the fact that, in most cases, the intensity of these unlisted beat points is relatively low. If, when calibrating the dial against a crystal check point, two beat notes are heard in the range of the CORRECTOR control, ALWAYS zero beat on the stronger of the two.

17. Frequency Measurements

a. General. Frequency Meter Set SCR–211–(&) may be used for measuring accurately a frequency emitted from an outside source, whether it be of local or remote origin, provided that the frequency lies within the calibrated range. Measuring such a frequency consists of adjusting the main tuning dial of the frequency meter until the frequency of the beat note heard in the headset is reduced to zero cycles per second, or zero beat. Rotating the main tuning dial varies the frequency of the variable frequency oscillator. When zero beat is obtained, either the frequency of the variable frequency oscillator is of the same frequency as the signal being measured, or some harmonic of the variable frequency oscillator is of the same frequency as the signal being measured. In order to know which of these conditions exists, it is necessary to know *approximately* the frequency of the signal being measured before measurement is made. This is very important, because in certain cases a condition of zero beat will be obtained at several different settings of the main tuning dial, and for each dial setting four frequencies are given in the calibration book. When the approximate frequency is known, however, the operator should refer to the calibration book for the approximate dial setting, and then find the exact frequency by varying the dial setting slightly from the approximate setting until zero beat is obtained. Figure 18 is a block diagram showing the operation of the frequency meter in determining the frequency of an external signal. The signal is known to be approximately 2,400 kc, as indicated by a receiver dial, for example. It is assumed that the frequency meter has been warmed up, calibrated, and set for operation at exactly 2,400 kc. Under these conditions a tone of 1 kc (1,000 cycles) is heard in the headset. Adjustment of the tuning dial in one direction causes the pitch of the tone to increase. This indicates moving away from the point of zero beat and is, therefore, the wrong direction. The operator must move the dial in the direction which causes the pitch of the tone to decrease and continue this movement until the zero beat point is reached. He must then note the dial reading, see the calibration book, and obtain the frequency of the incoming signal. In this particular example, the incoming frequency could be either 2,399 kc or 2,401 kc to produce the the original beat note (difference frequency) of 1 kc. In actual practice, the frequency of the incoming signal will not fall exactly on a point in the calibration book, and it will be necessary to interpolate. To do this, see paragraph 12e.

b. Measurement of Local Transmitter, Approximate Frequency Known. To measure accurately the emitted frequency of an adjacent transmitter or oscillator whose approximate frequency is known, first correct the variable frequency oscillator to the CRYSTAL CHECK POINT nearest to the approximate known frequency. Loosely couple the frequency meter antenna to the source, turn the operation switch to the proper operating condition, and move the frequency meter tuning control to the zero beat point found nearest the setting given for the approximate frequency. With the resultant dial setting, refer to the appropriate column in the calibration book to obtain the actual frequency. (See par. 12d.)

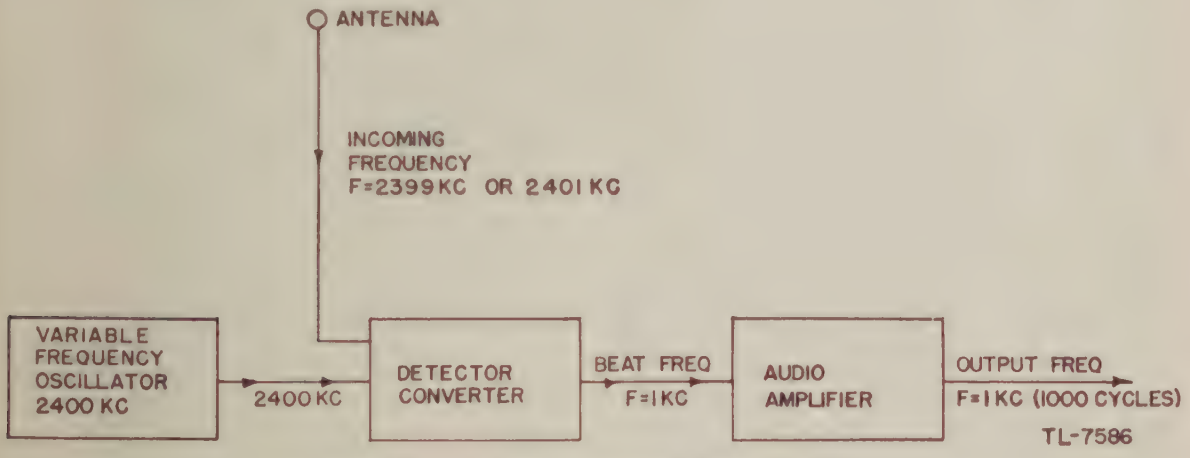


Figure 18. Block diagram, measurement of an external signal.

c. Measurement of Local Transmitter, Approximate Frequency Unknown. To measure accurately the emitted frequency of an adjacent transmitter or oscillator, the frequency of which is unknown, determine first the approximate frequency with the aid of an absorption type wavemeter or a radio receiver; then determine actual frequency, b above. *If the receiver is being used for the above measurement, make sure that it is not tuned to a harmonic of the transmitter under measurement.*

d. Measurement of Signal of Remote Origin. To measure accurately a frequency of remote origin, first tune the signal in on a radio receiver and note the approximate frequency from the receiver calibration. Next, correct the variable frequency oscillator to calibration at the CRYSTAL CHECK POINT nearest to the approximate frequency. Throw the operation switch of the frequency meter to the proper operating position, and loosely couple the frequency meter antenna to the receiver antenna lead. Then turn the frequency meter tuning control until its signal is heard in the receiver headset. If the signal in question is c-w, tune the receiver to zero beat, and tune the frequency meter to zero beat with the receiver. If the signal is modulated, first adjust the receiver for maximum response to the signal in the m-c-w condition; then tune the frequency meter to zero beat with the signal. (In some cases, the incoming signal may be of such low intensity that it will be blotted out by the strong signal from the frequency meter. If this occurs put the receiver into operation for c-w reception, zero beat the receiver to the incoming signal, and then zero beat the frequency meter to the receiver. If this cannot be done, reduce the coupling of the frequency meter.) For both the c-w signal and the modulated signal, the frequency read from the appropriate column in the calibration book is the desired frequency.

18. Precautions During Operation

a. Accuracy. The most important precaution to observe in the use of the frequency meter is proper adjustment of the CORRECTOR control. This adjustment corrects the accumulated errors due to temperature, humidity, and battery voltage variations, warm-up drift, and rough handling. For most accurate results, allow the frequency meter to warm up for about 15 to 20 minutes before giving the CORRECTOR control its final adjustment and making frequency measurements. If measurements are to be made over a long period of time, recheck the CORRECTOR at intervals at the CRYSTAL CHECK POINT used; readjust if the meter has drifted. Always adjust the CORRECTOR at the same temperature at which the instrument is used. For example, if the meter is taken from a heated building to be used outside when the weather is very cold, the greatest accuracy and greatest freedom from drift will be obtained if the meter is allowed to stand in the cold for a period of 30 minutes or more before the meter is turned on for the warm-up period. After the warm-up period under these conditions, the meter should be corrected in the usual fashion. Where circumstances do not allow such a long waiting period, the meter may be changed from one temperature to another without impairing its accuracy if it is recorrected *immediately* before making each measurement.

b. False Zero Beats. The frequency meter emits a number of frequencies simultaneously, the most useful of which are listed in the calibration book. On the LOW band, the fundamental frequency of the oscillator is 125 to 250 kc, and is listed in the left-hand column of the calibration chart. The second harmonic is two times the fundamental, covers 250 to 500 kc, and is listed in the second column. *The third harmonic, although not listed in the calibration book, is present in the output of the frequency meter and can produce a beat note almost as strong as the second.* It covers the frequency range of 375 to 750 kc. The fourth harmonic covers 500 to 1,000 kc and is listed in the third column. *The fifth, sixth, and seventh harmonics, not listed, are also present, and can produce relatively strong beat notes.* The eighth harmonic, 1,000 to 2,000 kc, is the highest harmonic regularly used for measurement. Harmonics above the eighth also exist but are progressively weaker as the order of harmonic increases. They can produce beat notes of corresponding lower strength. On the HIGH band the fundamental covers 2,000 to 4,000 kc, the second harmonic covers 4,000 to 8,000 kc, the fourth harmonic covers 8,000 to 16,000 kc, and the fifth harmonic covers 10,000 to 20,000 kc. These are all listed in the calibration book. *The third harmonic, covering 6,000 to 12,000 kc, is present and can produce a strong beat note, but is not listed in the calibration book.* The harmonics beyond the fifth are present in decreasing strength and are capable of giving correspondingly weaker beat notes. The presence of many unlisted harmonics makes it possible to obtain beat notes that are

very misleading and can be the cause of bad errors in frequency measurement or frequency adjustments.

NOTE. To be sure of the correct beat note, it is essential that the operator know the approximate calibration of the device he is measuring or adjusting.

c. BATTERY LIFE. Batteries of rather limited capacity are provided in the frequency meter set so that the instrument will not be too heavy. If used sparingly, the batteries will last for a long time. In most instances, the 15-minute warm-up periods far exceed the actual periods of measurement; therefore, any reduction in warm-up time prolongs the useful battery life. To determine the minimum length of time required for sufficient warm up, set the operation switch of the meter for check of the calibration at the nearest CRYSTAL CHECK POINT and leave the CORRECTOR control in such a position that an audible beat note is obtained. Then listen until the beat note has stopped drifting in frequency or is drifting very slowly to decide when the meter is stabilized enough to make reliable measurements. Readjust the CORRECTOR within 10 or 15 seconds of the time of actual measurement, thus cutting the warm-up period to a very few minutes, and lengthening the useful battery life. (Some of the later models of the SCR–211–(&) equipped with a WARM-UP position on the POWER or operation switch are preferable in this respect to the earlier models.)

Caution: High temperatures quickly shorten the life of the batteries. Never keep the instrument in a warm place. Store spare batteries, particularly *B* batteries, in a cool dry place.

d. STORAGE. When the Frequency Meter Set SCR–211–(&) is to be stored for a period exceeding *2 weeks,* remove the batteries from the instrument. If this is not done, severe damage to the interior of the meter may be the result of deterioration of the batteries.

19. Adjustments for Field Upkeep

In case of failure of the frequency meter due to defective tubes or oscillator crystal, spare tubes can be inserted in the proper sockets without the necessity of recalibrating the instrument.

Caution: Never disturb the adjustment of any of the interior trimmer capacitors. Avoid moving wires in any of the r-f circuits. This may cause the frequency of the instrument to vary from the corresponding frequency on the calibration chart.

Section III. FUNCTIONING OF PARTS

20. General

The functioning of the various parts of the Frequency Meter Set SCR–211–(&) is discussed in a general way in the paragraphs below. For more detailed functioning of parts and circuits and for all diagrams of any particular model or group of models, refer to the appropriate chapter.

21. Circuit Components

The circuit of the frequency meter may be divided into four parts.

a. Standard of reference, provided by a crystal-controlled oscillating circuit.

b. Variable frequency oscillating circuit, which generates frequencies determined by the setting of the main tuning dial.

c. Detector-converter stage, which detects the difference of the frequencies of these two independent circuits after combining the two frequencies electronically.

d. Audio-amplifying circuit, which amplifies the detected frequencies and feeds them to the PHONES jack, or jacks.

22. Crystal Circuit

The crystal-oscillator circuit uses a portion of the detector-converter stage. (See par. 21c.) It can be switched in and out of operation without disturbing the rest of the circuit. In some cases, the crystal itself is shorted out, and in others, plate voltage is removed from one of the elements of the tube. For exact details, see the chapter covering the model in question. The crystal has a natural frequency of 1,000 kc and will not change appreciably if the surrounding temperature, the tubes, and the power supply voltage are within the specified limits. The crystal is securely inclosed within an air gap type holder mounted in a standard metal tube envelope which has an octal base. The holder protects the crystal and shock, vibration, and humidity changes, therefore, cause little variation in its fundamental frequency.

a. CRYSTAL HARMONICS. The crystal controls a tube oscillator, which generates a constant frequency of 1,000 kc plus its harmonics. These harmonics are integral multiples of the fundamental; that is 2,000, 3,000, 4,000 kc, and so on. These harmonics have the same percentage of accuracy as the fundamental and can be used as reference frequencies throughout the range of the meter.

b. Application of the Crystal Circuit. (1) The crystal circuit has two functions.

(*a*) It serves as a standard frequency reference against which to test the variable frequency oscillator circuit.

(*b*) It is a source of 1,000 kc and harmonics of 1,000 kc, to be radiated from the meter antenna to some external instrument. (This is not the case in the BC–221–A, BC–221–C, or BC–221–D, since no provision is made in these models for allowing the crystal-oscillator circuit to operate with the variable frequency turned off.)

(2) The two functions are controlled by the operation switch of the frequency meter. For exact details see the chapter on the model in question.

23. Variable Frequency Oscillator Circuit

The variable frequency oscillator circuit of the frequency meter consists of several essential elements.

a. Tuning Capacitor. This capacitor is very stable and is a feature inherent in the circuit design. It is rotated by a precision type worm wheel and worm. The tuning dial is attached to the worm shaft and can be locked at any setting by means of the dial lock. The dial lock is designed so that locking will not cause a shift of more than 30 cycles at 4,000 kc. A small adjustable padding capacitor across the tuning capacitor is the CORRECTOR control.

b. Coils. There are two coils in the variable frequency oscillator circuit, one for the LOW band and one for the HIGH band. The terminals of either coil are connected across the terminals of the tuning capacitor by the FREQ. BAND LOW-HIGH band selector switch. Each coil and its associated capacitors constitute the resonant circuit that determines the output frequency of the variable frequency oscillator tube. In these circuits, every effort has been made to reduce to a minimum all frequency variations due to warming up of the tubes and circuit components, variations in battery output voltage, and temperature and humidity changes. These results are obtained in different ways in the various models. For specific details see the chapter on the model in question.

c. Band Selector Switch. This switch changes the internal circuits of the variable frequency oscillator to either LOW or HIGH band operation. See the chapter on a specific model for further details.

d. Circuit Corrector. The CORRECTOR is a small variable capacitor across the main tuning capacitor. It enables the operator to so control the total capacitance across the oscillator tuned circuit, as to compensate for slight changes in the circuit.

e. Trimmer Capacitors. To insure a straight line frequency operating curve and a frequency range that covers virtually the entire dial, it is necessary to control carefully the fixed capacitance in the resonant circuits. This is done by adjusting either one of the two padding capacitors depending upon the position of the FREQ. BAND LOW-HIGH switch. These capacitors are used to build up the fixed capacitance of each circuit to the exact values called for by the design of the variable tuning capacitor.

Caution: The trimmer capacitor settings are made at the factory. Do not tamper with them. To do so may throw the meter completely off calibration and necessitate expensive realignment.

f. Oscillator Function. The variable frequency oscillator is the source of the frequencies used in making frequency checks on receivers and transmitters. Its operation is controlled by the operation switch of the frequency meter. In one position of the switch, the output of the oscillator is mixed with the output frequency of the crystal-oscillator circuit. The resulting frequency, the beat frequency, is equal to the difference between the two and is used in calibrating the meter at a crystal check point. In another position of the operation switch, the variable frequency oscillator circuit is in operation, but the crystal circuit is turned off. If the antenna is in position, the frequency meter is used to receive or radiate any frequency in its range; that is, it is used as a radio receiver or transmitter. For further details of operation as applied to a particular model, refer to the chapter on that model.

24. Detector Tube Circuit

A dual-purpose type vacuum tube is used in the detector-converter stage of all models of Frequency Meter BC–221–(&). In the early models, a pentagrid-converter type circuit is used, whereas the later models use a triode-hexode type of tube. In either case, the tube can be considered as having two control grids: the oscillator control grid and the detector control grid. When measurements are made on transmitters, energy

from the transmitter is picked up by the antenna of the frequency meter and fed through coupling capacitors to the control grid of this detector tube. Output voltage from the variable frequency oscillator is coupled to the same grid by means of another capacitive coupling arrangement. When the frequencies differ by only a few hundred cycles, a distinct audio beat note (equal in frequency to the difference between the two impressed frequencies) is produced in the plate circuit of the detector and passed on to the audio amplifier. When the operation switch of the frequency meter is thrown to the position used for checking the frequency of the variable frequency oscillator against the output of the crystal oscillator, the output voltage from the variable frequency oscillator is again impressed on the control grid of the detector tube. There it is mixed, by electron coupling, with the output of the crystal oscillator. The output (plate) circuit of the detector-converter stage is made responsive to low audio frequencies by the use of a high inductance choke coil in its plate circuit. In some models, the high frequency response of this coil is reduced by means of a capacitor across this choke.

25. Audio-Amplifying Circuit

The audio amplifier is a conventional, self-biased, triode-connected circuit. Some of the early models employ a triode tube in this circuit while the later models use a pentode tube, connected as a triode. This is done in order to simplify the supply problem on replacement tubes since in most cases, the tube so used is the same type as the tube used in the variable frequency oscillator stage. Some variations in this procedure may be noted by reference to the chapter on the particular model involved. The audio signal passed on to the headset can be adjusted manually by means of the GAIN control to suit the operator's requirements. As a precaution to prevent shocks to the operator, the headset is operated at the same d-c potential as the chassis. In some models, the high plate voltage is blocked off the headset by means of a blocking capacitor. In the later models, an audio-output transformer is used. Since there are no terminals that have an appreciable voltage difference between themselves and the chassis, there is no danger of the operator receiving a shock during operation, provided the instrument is in its case, and there is no connection from the case or the ANT connection to any other object at a voltage above ground.

NOTE. Switching from low to high band, switching from the checking position to the crystal position or vice versa, or operating any of the controls, may cause the detector grid to block and the instrument to stop operating. If this happens, turn the instrument off and then on again.

Section IV. MAINTENANCE

NOTE. Unsatisfactory performance of this equipment will be reported immediately on W.D., A.G.O. Form No. 468. If form is not available see TM 38-250.

26. General Instructions

This equipment is extremely accurate and sensitive. Handle it as carefully as any precision instrument.

a. REPLACEMENT OF PARTS. The accuracy of calibration is affected by replacement of certain parts. In view of the precision required, the policy governing the maintenance of Frequency Meter Set SCR–211–(&) is given below.

(1) *Zone of the interior.* (*a*) Repairs and replacement of parts, other than tubes, within the variable frequency oscillator circuits and crystal oscillator circuits of Frequency Meter Set SCR–211–(&), and/or recalibration of these instruments, are designated fifth-echelon maintenance, and are limited to the following signal depot repair shops:

Philadelphia Signal Depot Repair Shop.
Sacramento Signal Depot Repair Shop.
Chicago Signal Depot Repair Shop.

(*b*) Frequency Meter Set SCR–211–(&), requiring repairs and/or recalibration as outlined in (1) (*a*) above, will be replaced through normal supply channels if possible, or shipped to one of the above depots.

1. First, Second, Third, and Fourth Service Commands will forward units to Philadelphia Signal Depot Repair Shop.
2. Fifth, Sixth, Seventh, and Eighth Service Commands will forward units to Chicago Signal Depot Repair Shop.
3. Ninth Service Command will forward units to Sacramento Signal Depot Repair Shop.

(*c*) For Frequency Meter Set SCR–211–(&) in need of repairs other than those specified in (*a*) above, normal echelons of maintenance will be followed.

(*d*) Unserviceable Frequency Meter Set SCR–211–(&) which is considered justifiable to repair will be completely reconditioned and recalibrated at the Philadelphia, Sacramento, or Chicago Signal Depot Repair Shops.

(*e*) Unserviceable Frequency Meter Set SCR–211–(&) which is considered beyond justifiable reconditioning will be disposed of in accordance with existing regulations for the reclamation of usable parts or salvaging, as the case may be.

(2) *Theaters of operation.* (*a*) Repairs and replacement of parts, other than tubes, within the variable frequency oscillator circuit and crystal oscillator circuit of Frequency Meter Set SCR–211–(&), are designated fifth-echelon maintenance and will be limited to those shops, in addition to the three shops mentioned in (1) (*a*) above, having the following equipment:

1. Primary and secondary frequency standards.
2. Temperature-controlled chamber, capable of housing the SCR–211–(&) and capable of varying and maintaining temperature from —40° C. to +60° C.
3. Adequate indicating equipment for determining temperature of frequency meter under test.
4. Recalibration of these instruments will be designated fifth-echelon maintenance and will be limited to those fifth-echelon shops having primary and secondary frequency standards.

(*b*) If return of Frequency Meter Set SCR–211–(&) to any of the repair shops designated in (2) (*a*) above is not practical, or the condition of the frequency meters does not warrant their reconditioning, they will be salvaged within existing regulations.

(*c*) For those Frequency Meter Sets SCR–211–(&) in need of repairs in the audio amplifier stage and/or replacement of tubes in all circuits, normal echelons of maintenance will be followed.

b. Figures and Diagrams. The figures and diagrams in this manual are useful in locating the causes of trouble. Each circuit element is identified by means of a symbol number which appears in the wiring diagrams. For complete understanding of the operation of the equipment these diagrams should be referred to frequently. A diagram is always furnished as part of the frequency meter cabinet. In case of doubt concerning the accuracy of a diagram in this manual (minor changes may have been made during manufacture), always be governed by the diagram accompanying the equipment.

c. Servicing. Little servicing should be required other than checking the battering voltages occasionally and testing the tubes after every 6 months of operation. No lubrication of any part is required except for two or three drops of PS–Oil, lubricating, preservative, special (all temperature, Specification No. AXS–777) applied to worm and worm gear of the main tuning capacitor after each 1,024 hours of operation or whenever the set is being serviced at Signal Corps repair depots. If the interior of the battery compartment shows damage due to unavoidable chemical deterioration of the batteries, clean the compartment thoroughly with aqueous ammonia solution, naptha, benzine, or pure gasoline to neutralize the effects of the battery chemicals.

d. Spare Tubes. Stock tubes selected at random should work satisfactorily in the detector-converter and audio-amplifier stages of this equipment. The variable frequency oscillator tube is the most critical. For best results, use tubes furnished with the equipment as running spares whenever possible. Stock tubes may show somewhat less stability particularly against humidity and temperature variations or against initial warm-up drift; however, they will operate and can be used in an emergency even though the accuracy of the meter may be slightly impaired.

e. Cleaning. An air blast is recommended for cleaning the instrument, provided the air is absolutely free from moisture and oil. The blast should be low in pressure, otherwise the trimmer and CORRECTOR capacitor plates may be bent, thereby destroying the accuracy of the calibration.

Caution: Do not unwire or remove any parts, nor disturb the position of the wiring. To do so may necessitate complete recalibration of the meter.

f. Control Knobs. If the control knobs become loose on their shafts, tighten the setscrews holding the knobs with the wrench or wrenches provided. Never use these wrenches for any other purpose.

g. Removal from Service. When the set is not in use, always be sure that the switches are set to the OFF position. It is true that removal of the headset plug from the PHONES jack opens up the filament circuit, but in some of the early models (BC–221–A, BC–221–C, and BC–221–D) a constant drain on the *B* battery will take place if the POWER switch is left ON. Keep the meter and the headset in the bag; keep the strap attached to the bag. If the set is to remain unused for a period exceeding 2 weeks,

remove the batteries.

27. Circuit Trouble

Faulty operation may be due to failure of the power supply, the headset, the crystal-oscillator circuit, the variable frequency oscillator circuit, the detector-converter circuit, or the audio-amplifier circuit. If the following simple tests are applied, the trouble may be located easily, and the amount of necessary checking or testing reduced greatly.

a. Checking Power Supply. The batteries may be checked under normal load conditions as follows: Plug a headset into the PHONES jack, turn on the frequency meter in the maximum load position of the operation switch (see chapter on applicable model), and allow about 1 minute for the tubes to warm up. Open the battery compartment, and on the battery terminal strip measure the *B* voltage between B+ and A–B– terminals with a volmeter having a full scale range of at least 150 volts, and 1,000 ohms per volt sensitivity.

Caution: Do not touch both terminals at the same time. A serious shock may result.

Measure the *A* voltage between the A+ and A–B– terminals with a voltmeter having a full scale range of at least 6 volts. If the total *B* voltage is below 121.5 volts, or the total *A* voltage below 5.4 volts, replace the batteries. When replacement of the batteries is necessary, installing an entirely new set of batteries is recommended, rather than replacing individual cells or batteries that may read low.

b. Checking Headset. To test the headset, proceed as follows: Remove the plug from the frequency meter and open the battery compartment. Then listening to the headset, touch the tip of the phone plug several times to one terminal of a 1.5-volt *A* battery cell (known to be good), while holding the sleeve of the plug in contact with the other terminal of the cell. A distinct click should be heard each time the contact is made or broken. If no click is heard, the headset or cord is defective. An alternate method of testing is to check the circuit with an ohmmeter or continuity meter by making connections to the tip and sleeve of the plug.

c. Checking Crystal Oscillator. To test the crystal-oscillator circuit, turn the operation switch of the meter for use of the crystal oscillator only (see chapter on model involved). Under normal conditions, the meter is radiating the crystal frequency at this position, and an oscillating receiver, or one adjusted for c-w reception, tuned to this frequency (1,000 kc. or any whole multiple of 1,000 kc) should readily detect the radiated signal.

d. Checking Variable Frequency Oscillator. To check the variable frequency oscillator circuit, turn the operation switch of the frequency meter for normal operating conditions (crystal oscillator not operating) and repeat the operations described in c above. In this test, however, the main tuning dial of the meter will have to be set to a known value of frequency and picked up on the receiver tuned for the same frequency.

e. Checking Detector-converter and Audio-amplifier Circuits. If all of the preceding tests indicate that the items or circuits tested are in operating condition, and trouble still persists, the detector-converter or audio-amplifier circuits may be defective. To test the audio-amplifier circuit, remove the frequency meter chassis from the case and connect it to the power supply by means of clip leads, or more conveniently, by means of an adapter cable made up for that purpose. With the meter in operating condition, turn the GAIN control clockwise (to the right). While listening in the headset, remove the detector-converter tube from its socket. If the audio-amplifier circuit is operating, a loud click will result. In any defective circuit, withdraw and reinsert the tube or crystal once or twice to insure good contact in the socket. If there is no improvement, replace the doubtful item with its spare. If the trouble still exists, it will be necessary to turn the meter in for repair.

28. Moistureproofing and Fungiproofing

a. General. Failures commonly occur when Signal Corps equipment is operated in tropical areas where temperature and relative humidity are extremely high. The following problems are typical:

(1) Resistors and capacitors fail.

(2) Electrolytic action takes place in coils, chokes, transformer windings, etc., causing eventual break-down.

(3) Hook-up wire and cable insulation breakdown. Fungus growth accelerates deterioration.

(4) Moisture forms electrical leakage paths on terminal boards and insulating strips causing flash-overs or leakage.

b. Treatment. A moistureproofing and fungiproofing treatment has been devised which, if properly applied, provides a reasonable degree

of protection against fungus growth, insects, corrosion, salt spray, and moisture. The treatment involves the use of a moisture- and fungi-resistant varnish applied by means of a spray gun. A brief description of the method of application follows:

(1) All repairs and adjustments necessary for the proper operation of the equipment are made.

(2) Equipment to be processed is thoroughly cleaned of all dirt, dust, rust, fungus, oil, and grease.

(3) Equipment is partially disassembled and certain points, such as open switches, air capacitors, sockets, bearings, etc., are covered with masking tape.

(4) Equipment is thoroughly dried by heat to dispel moisture which the circuit elements have absorbed.

(5) All circuit elements and all parts of the equipment are sprayed or painted with three coats of moistureproofing and fungiproofing varnish.

(6) The equipment is given a final operational check; radio sets receiving a 24- to 36-hour aging period, when time permits, before return to service.

c. Step-by-Step Instructions. The following are step-by-step instructions for the treatment of Frequency Meter BC–221–(&):

(1) *Disassembly.* (*a*) Remove the chassis of Frequency Meter BC–221–(&) from the cabinet.

(*b*) Remove the crystal, and spare crystal if one is present, from the chassis.

(2) *Masking.* (*a*) Cover contacts and openings of PHONES jacks with masking tape.

(*b*) Cover prong or clip of antenna contactor with masking tape.

(*c*) Cover grid cap of detector-converter tube with masking tape.

(*d*) Cover CORRECTOR trimmer capacitor with masking tape.

(*e*) Cover contacts, or push paper in so that it covers contacts, on *all* switches.

(*f*) Cover all prongs on power supply plug assembly with masking tape.

(*g*) Cover openings on variable capacitor cover shield with masking tape.

(*h*) Cover the HIGH and LOW trimmer capacitors with masking tape.

(*i*) Cover any openings in the shield of the main tuning capacitor with masking tape.

Caution: Make sure that a complete job of masking has been done on the items listed above. If the spray chemicals get on any of the variable capacitors, the calibration of the instrument will be destroyed.

d. General Instructions. For general instructions in the spray method of moistureproofing and fungiproofing see TB SIG 13.

Section V. SUPPLEMENTARY DATA

29. General

a. Components and parts are dependent upon the model of Frequency Meter Set SCR–211–(&). Therefore, a list of components and a tabular list of maintenance parts have been made up for each different model or group of models, and these lists will be found in the chapter on the model in question. If the schematic diagrams of the various models of a group of models happen to differ, each variation will be covered by a separate diagram. In cases in which most of the parts are identical but have different circuit number designations, these differences are pointed out.

b. A number of photographs covering miscellaneous views of various models are included at the end of this chapter. (See figs. 19 to 27, incl.)

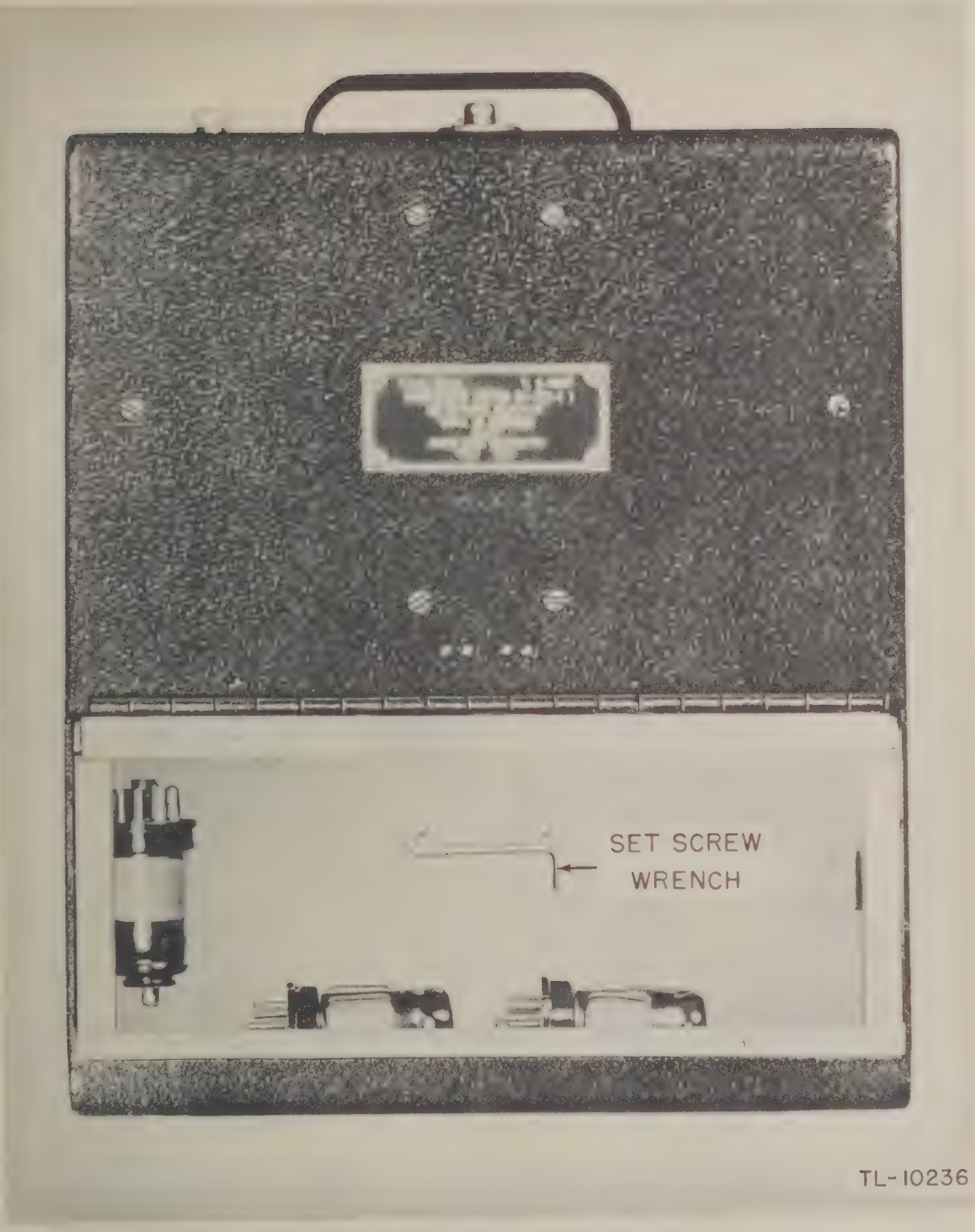


Figure 19. Frequency Meter BC–221–T, view of spare parts compartment.

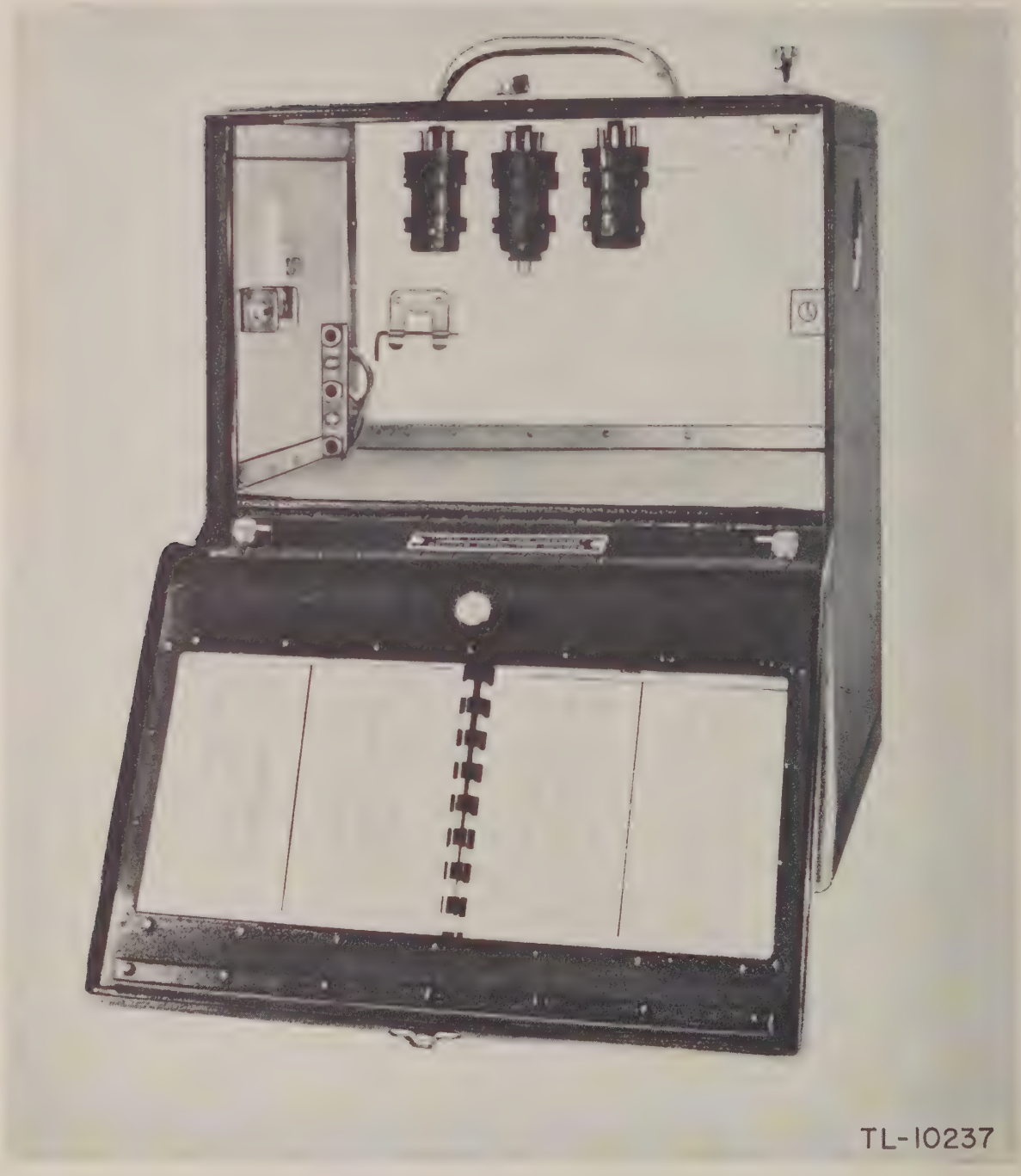


Figure 20. Frequency Meter BC–221–B, view of cabinet interior and calibration book.

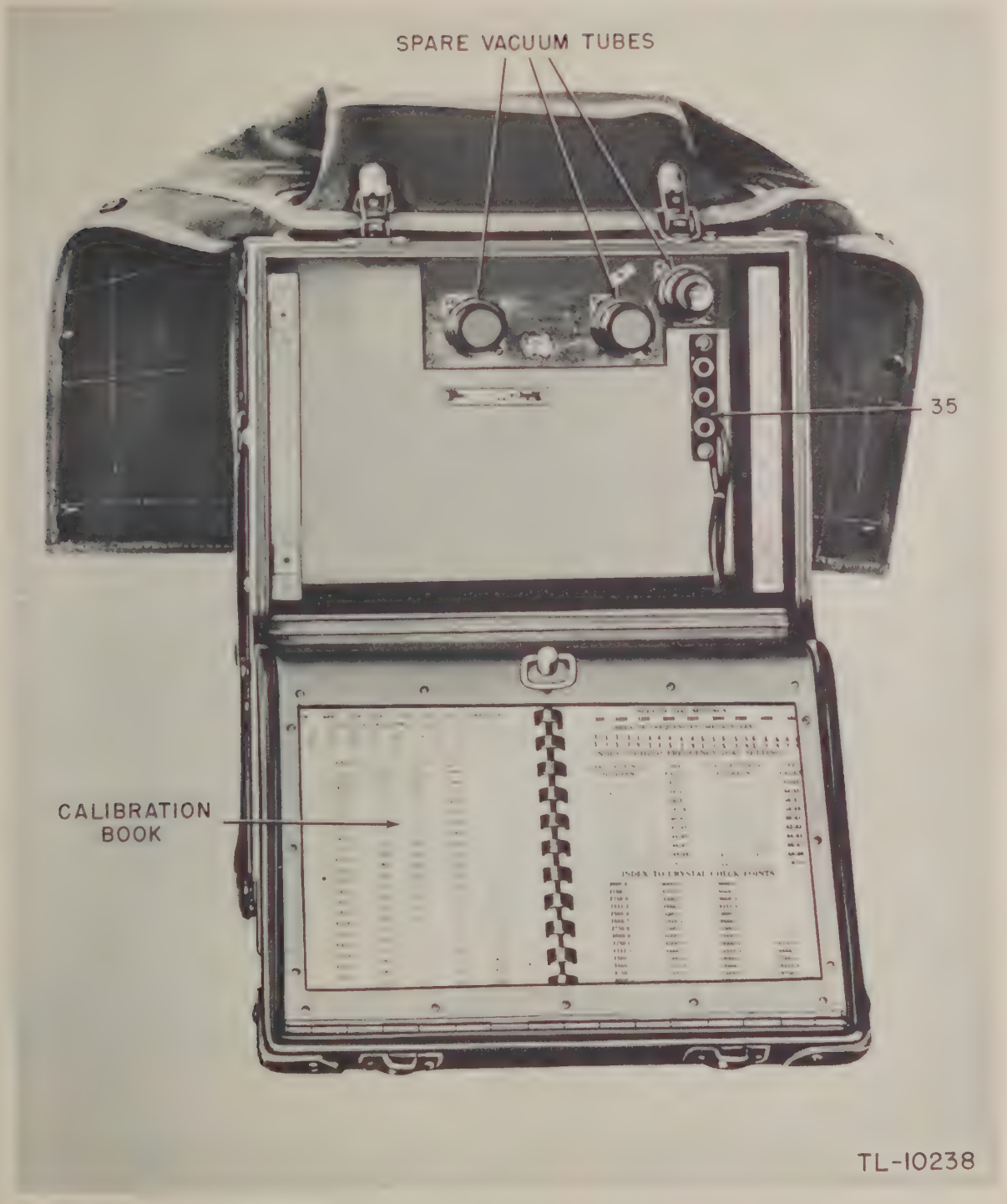


Figure 21. Frequency Meter BC–221–AF, view of cabinet interior and calibration book.

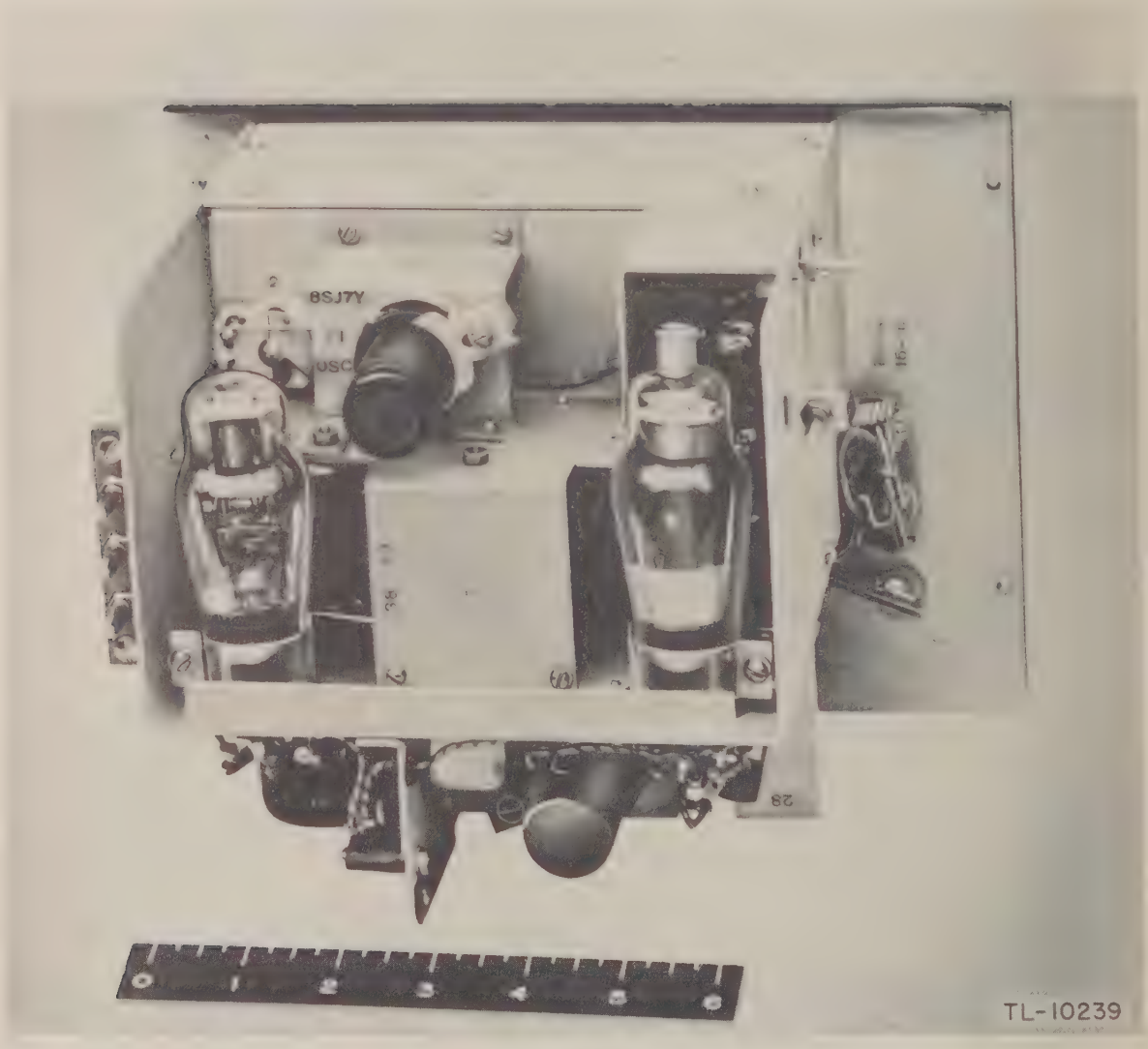


Figure 22. Frequency Meter BC–221–F, rear view of chassis.

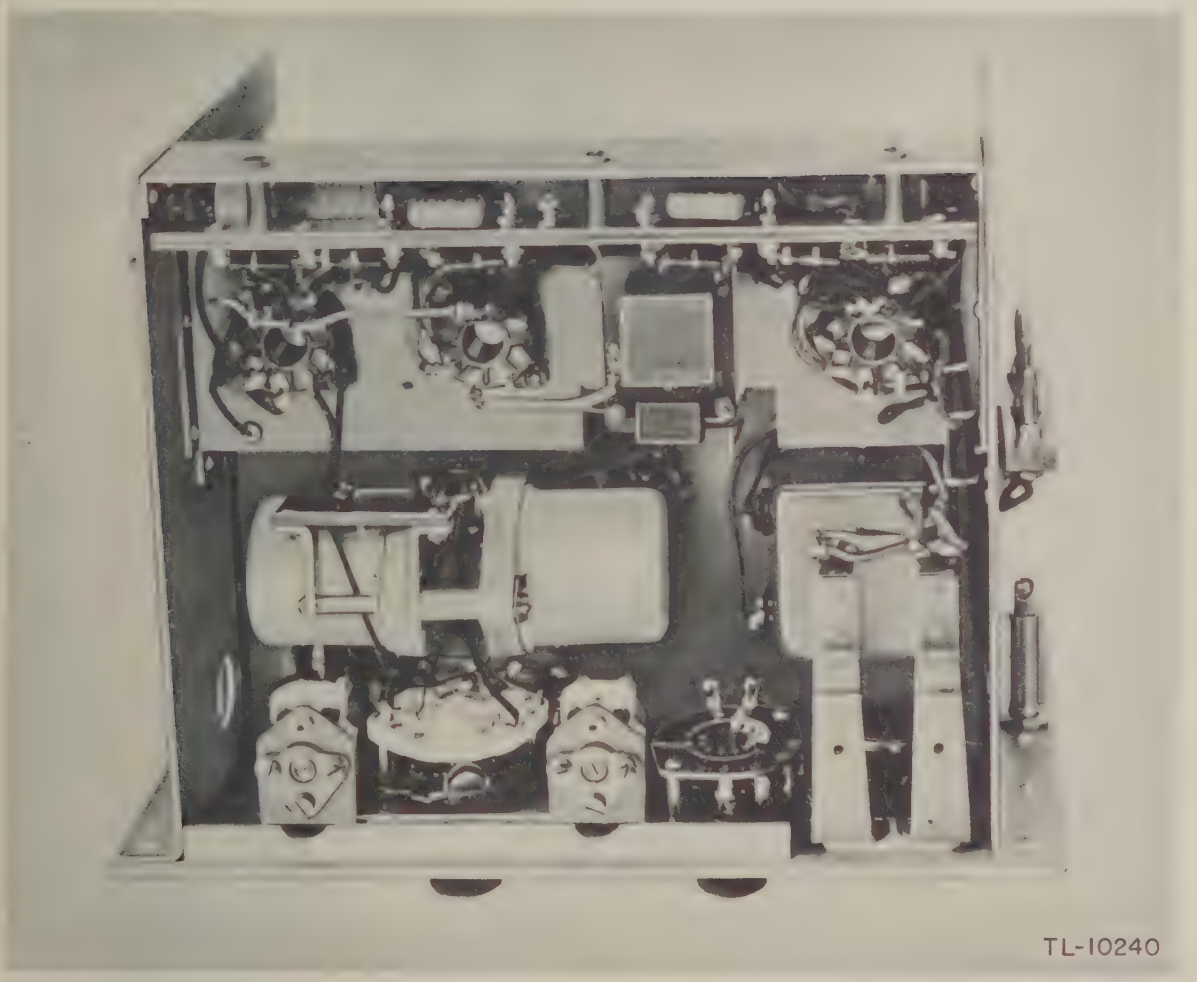


Figure 23. Frequency Meter BC–221–B, bottom view of chassis with coil shield removed.

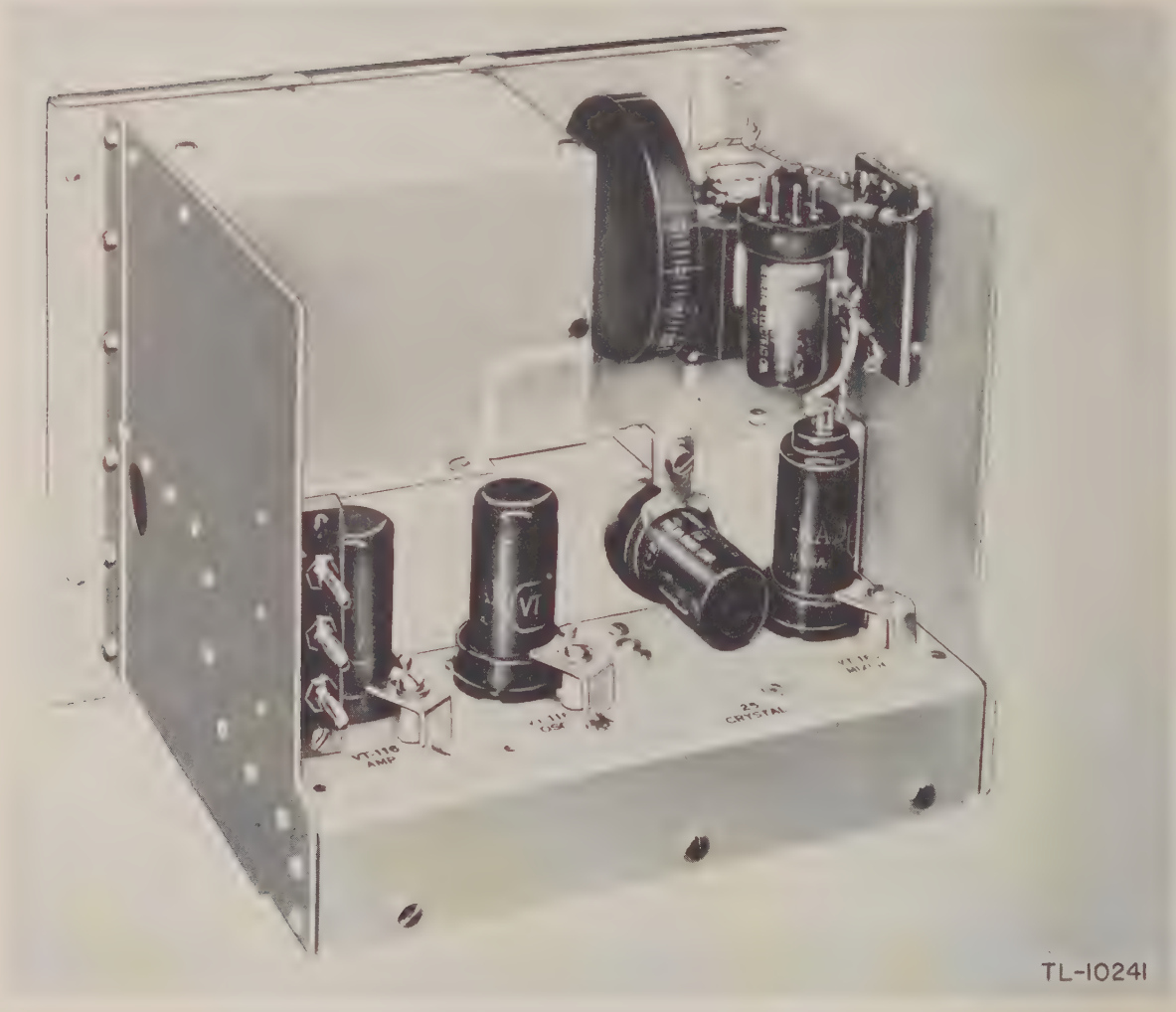


Figure 24. Frequency Meter BC–221–AA, rear view of chassis.

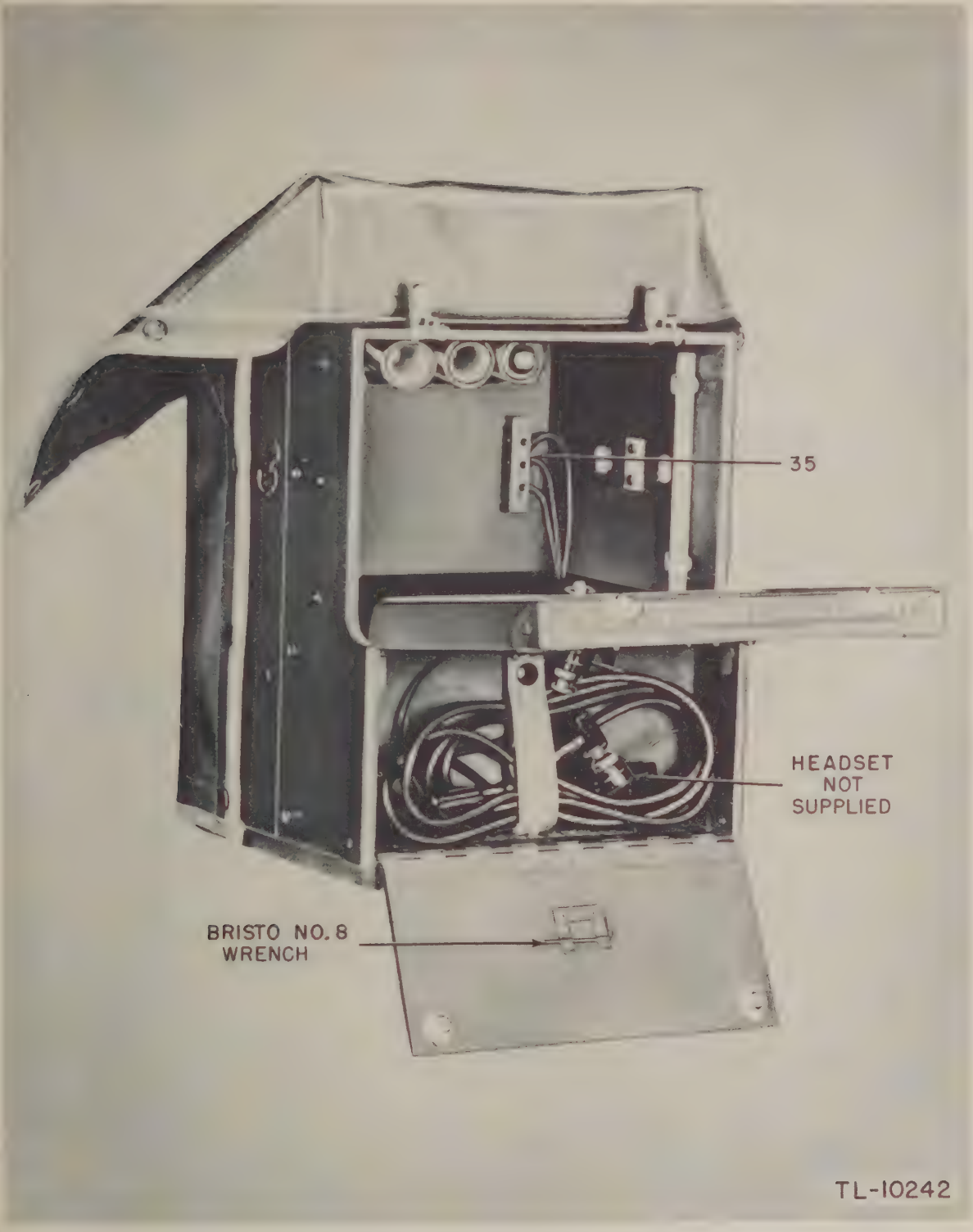


Figure 25. Frequency Meter BC–221–(&), typical wooden cabinet, showing headset compartment.

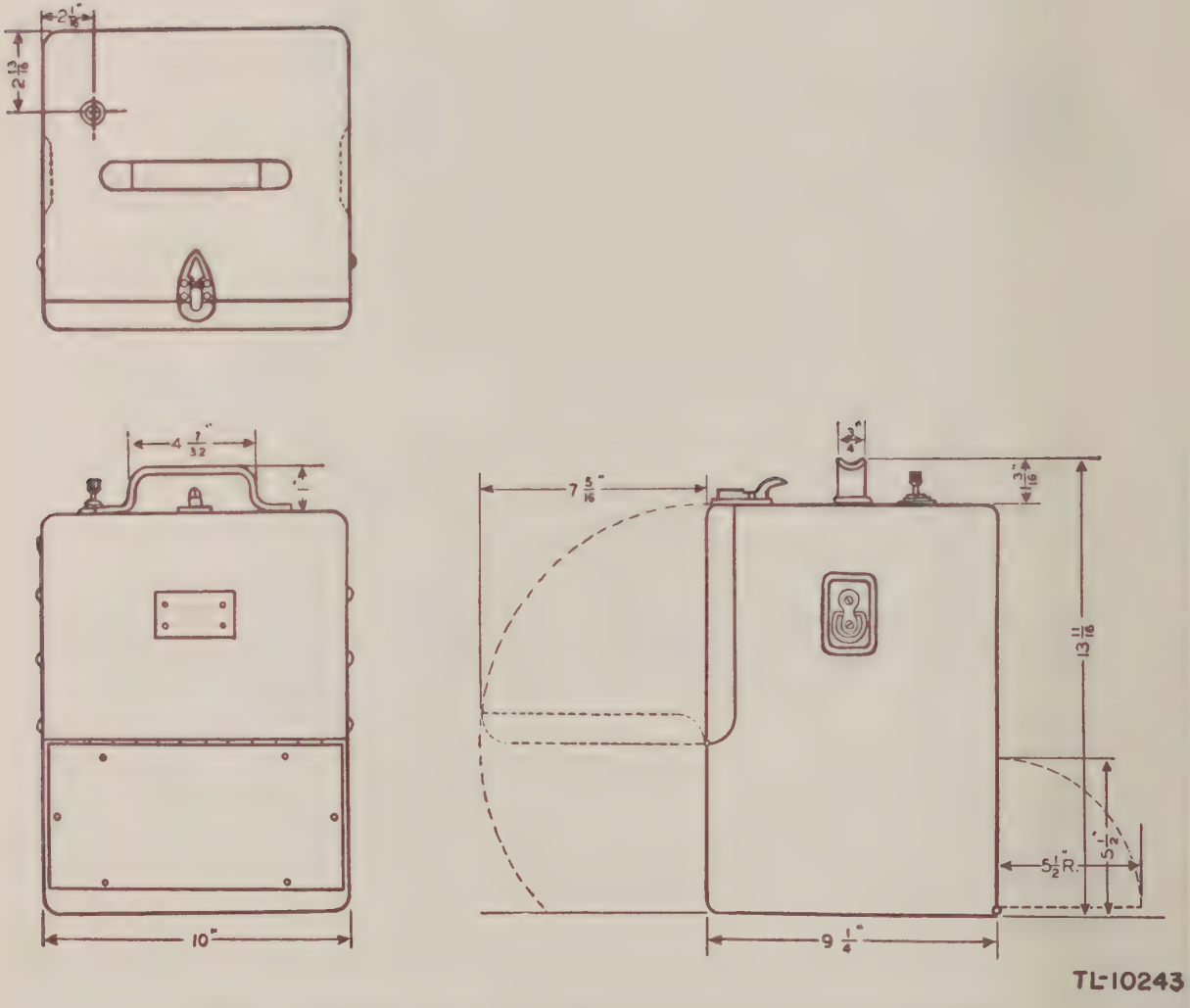
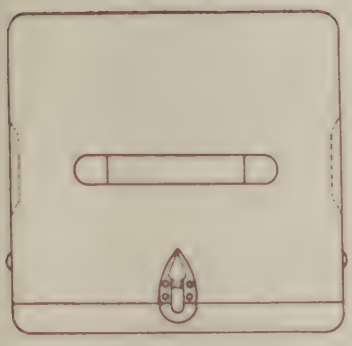
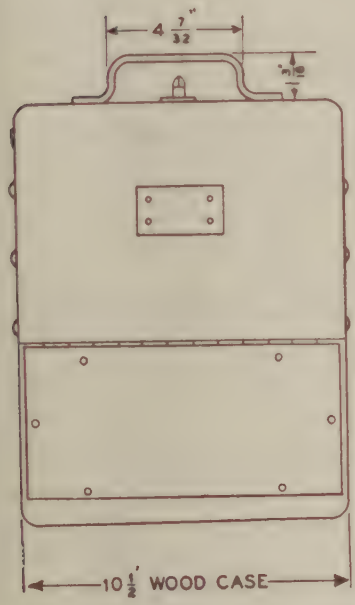


Figure 26. Frequency Meter BC–221–(&), typical dimensions, metal cabinet (subject to slight variations.)





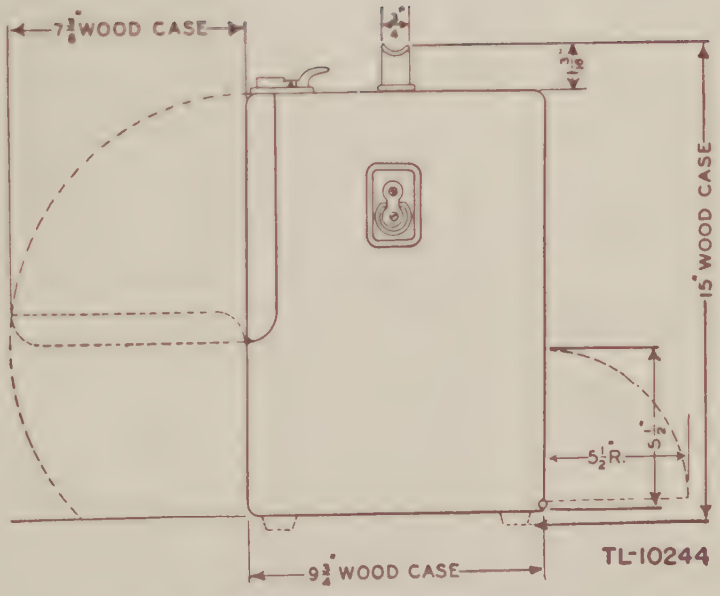


Figure 27. Frequency Meter BC-221-(&), typical dimensions, wooden cabinet (subject to slight variations).

CHAPTER 2

FREQUENCY METER SETS SCR–211–A, SCR–211–C, AND SCR–211–D

Section I. DESCRIPTION

30. General

Frequency Meter Sets SCR–211–A, SCR–211–C, and SCR–211–D have been manufactured by the Bendix Radio Corporation on several different orders. Sets SCR–211–C and SCR–211–D are identical in all major respects and are treated as such in this chapter. Set SCR–211–A differs from the SCR–211–C and the SCR–211–D in two minor respects. The only noticeable difference in internal appearance between the SCR–211–A, the SCR–211–C, and the SCR–211–D is that in the two latter sets the spare crystal is mounted on the under side of the chassis instead of on the left side wall. Electrically, except for the addition of two small fixed resistors, 20–1 and 21–1, capacitor 7–1C, and a change in the connection of the suppressor grid of the variable frequency oscillator tube, the circuit of the SCR–211–C or the SCR–211–D is identical with that of the SCR–211–A. It should be noted also that the part numbers in the schematic diagram of the SCR–211–A differ from the part numbers of the SCR–211–C and the SCR–211–D, but the value and function of similar parts is the same in spite of the difference in part numbers. For further general information see paragraph 2. The symbol (1) as used throughout this chapter refers to either the SCR–211–A, SCR–211–C, or SCR–211–D.

31. Components

Each Frequency Meter Set SCR–211–(1) includes the following component units:

Quantity	Component
1	Frequency Meter BC–221–(1) includes: 1 Crystal Unit DC–9–(1) (in operating position). 1 Crystal Unit DC–9–(1) (spare, mounted on chassis). 1 Calibration Book MC–177–(1). 1 Calibration Book MC–177–(1) (spare, untyped, in chassis compartment). 1 wrench for Bristo No. 6 setscrew (spares compartment). 1 wrench for Bristo No. 8 setscrew (spares compartment).
2	Tube VT–77, type 77 (one in use, one spare).
2	Commercial tube type 6A7 (one in use, one spare).
2	Tube VT–76, type 76 (one in use, one spare).
1	Preliminary instruction book, or technical manual for Frequency Meter Set SCR–211–1(1).
1	Bag BG–81–(1).
1	Additional spare set of vacuum tubes (one each; supplied in bulk).

32. Additional Equipment Required

The following equipment, not furnished with the orders, is required to complete each Frequency Meter Set SCR–211–(1):

Quantity	Article
1	Headset P–18 or P–20.
6	Batteries BA–2.
4	Batteries BA–23.
1	Strap ST–19–A.

33. Total Weight

Frequency Meter Set SCR–211–(1), complete and ready for service, weighs 38.5 pounds. For typical dimensions, see figure 26.

34. Power Consumption

All power required for the operation of this equipment is supplied by the batteries listed in paragraph 32. The following are the current drains at the specified voltage limits.

a. For the SCR–211–A:

Filaments: 5.4 to 6.0 volts, 0.86 to 0.91 ampere.

Plates, etc.: 121.5 to 135.0 volts, 0.0091 to 0.0106 ampere.

b. For the SCR–211–C and SCR–211–D:

Filaments: 5.4 to 6.0 volts, 0.86 to 0.91 ampere.

Plates, etc.: 121.5 to 135.0 volts, 0.013 to 0.017 ampere.

c. These values are typical for operation with the CRYSTAL switch in the OFF position, under which condition maximum plate current is drawn.

35. Controls (par. 2e)

When the snap latch is released and the front cover lowered, the control panel and calibration book are exposed. There are seven operating controls (fig. 3):

a. A single PHONES jack accommodates the headset issued with the frequency meter. The headset must be plugged in before the meter can be set in operation because of the series filament supply switch built into the jack.

b. The POWER OFF-ON switch breaks both the filament and plate supply voltages and, in connection with the PHONES jack, controls the operation of the meter.

c. The GAIN control is a volume control used to adjust the input voltage to the audio-amplifer tube and, in turn, the level of sound in the headset.

d. The CRYSTAL OFF-ON switch permits the insertion or removal of the crystal oscillator from the meter circuit. In the OFF position of the switch, the crystal is shorted out. In the ON position the short around the crystal is removed. The CRYSTAL ON position is used primarily for checking the variable frequency oscillator at CRYSTAL CHECK POINTS.

Caution: In the frequency meter set SCR–211–(1), the circuit design is such that the variable frequency oscillator is always in operation with the power switch in the ON position. Therefore, the crystal oscillator cannot be used as a source of 1,000 kc (and whole multiples of 1,000 kc) because confusion will be caused by the output of the variable frequency oscillator. To obtain 1,000-kc signals, adjust the variable frequency oscillator in the usual way for the frequency desired.

e. The FREQ. BAND LOW-HIGH switch permits the selection of the appropriate band of operation of the variable frequency oscillator as indicated by the frequency being checked or calibrated.

f. The frequency of the variable frequency oscillator is controlled by setting the dial labeled DIAL UNITS which is graduated into one hundred divisions. One revolution of the DIAL UNITS dial moves the DIAL HUNDREDS dial one division. (See par. 11.)

g. The CORRECTOR knob controls a small variable capacitor across the variable frequency oscillator tuned circuit, and is used to compensate for small changes in capacitance brought about by temperature, humidity, and mechanical changes. It is adjusted at each CRYSTAL CHECK POINT to make the calibration of the instrument as accurate as possible over that part of the scale centered at a given CRYSTAL CHECK POINT and extending halfway to the next higher and next lower CRYSTAL CHECK POINTS.

36. Vacuum Tubes

The vacuum tubes used in Frequency Meter Set SCR–211–(1) are shown in the following tabulation:

Reference	Function	Signal Corps type nomenclature	Commercial equivalent	Base
VT–77	Variable frequency oscillator	VT–77	77	Small 6-pin
6A7	Crystal oscillator and detector.	None	6A7	Small 7-pin
VT–76	Audio-frequency amplifier.	VT–76	76	Small 5-pin

Section II.
INSTALLATION AND OPERATION

37. Initial Procedure (par. 7)

If the second set of spare tubes, inclosed in a carton, is stored in the battery compartment, remove it when inspecting the equipment and place it in stock.

38. Installation of Batteries (par. 8)

Remove the frequency meter chassis from the cabinet when installing the batteries. Open the battery compartment in the lower rear of the frequency meter cabinet and loosen the binder-head screw on the right-hand outer side, in order to release the metal strap which secures the filament battery. Insert the four Batteries BA–23 under the strap and push them well forward with the terminal posts facing the rear of the cabinet. Before tightening the securing strap, hold the wiring harness in such a position that the two lugs of the main cables align with the A+ and A–B– terminals on the battery terminal board, and arrange the four battery cells so that the terminal posts match up with the individual battery lugs on the harness (the eight terminals on the circumference of a circle as in fig. 12). Tighten the securing strap with the batteries in this position. Then connect the six Batteries BA–2 in series, and insulate the splices with friction tape or spaghetti to prevent short circuits. Assemble the six batteries in two layers of three each, with the top layer inverted. See that the minus and plus 135-volt leads are free for connection to their respective terminals on the terminal board. Insert the batteries in the cabinet, connect them to the terminal board, and install the filament battery wiring harness.

Caution: When batteries are being loaded into the battery compartment, do not touch the connecting leads. A severe shock may result. Do not short-circuit the terminals of the terminal board while making connections.

After replacing the frequency meter chassis, check the battery installation as indicated in paragraph 8d.

39. Antenna (par. 9)

40. Headset (par. 10)

Plug Headset P–18 or P–20 in the PHONES jack. Then turn the POWER and CRYSTAL switches to the ON positions. Allow the vacuum tube filaments to heat for 15 to 20 minutes. The equipment will then be ready for use.

41. Reading the Dial (par. 11)

42. Calibration Book MC–177–(1) (par. 12)

43. Operating Circuits (par. 13)

44. Zero Beat Detection (par. 14)

45. Correction in Calibration

With the POWER and CRYSTAL switches turned to the ON position, follow the procedure described in paragraph 15. After completion of this procedure, turn the CRYSTAL switch to the OFF position and proceed with any measurements.

46. Crystal Check Points (par. 16)

47. Frequency Measurements

The proper position for the CRYSTAL switch for all measurements other than the correction of the variable frequency oscillator is in the OFF position. For details on making frequency measurements read paragraph 17.

48. Precautions During Operation (par. 18)

49. Adjustments for Field Upkeep (par. 19)

Section III. FUNCTIONING OF PARTS

50. General

The part numbers of Frequency Meters BC–221–C and BC–221–D are exactly alike. The part numbers of the BC–221–A differ, however, although the circuit functions of similar parts are the same. In order to describe all three sets together, a special numbering system is used in this section. The numbers in parentheses apply to the BC–221–C and the BC–221–D, while those not in parentheses apply to the BC–221–A. For example, the designation 22 (18) means part No. 22 of the BC–221–A and part No. 18 of the BC–221–C or BC–221–D. This numbering system applies throughout this section. For further details see figures 31 and 32.

51. Circuit Components (par. 21)

52. Crystal Circuit

The cathode, the inner grid, and the anode grid of the type 6A7 tube constitute the active elements of a crystal-controlled triode oscillator

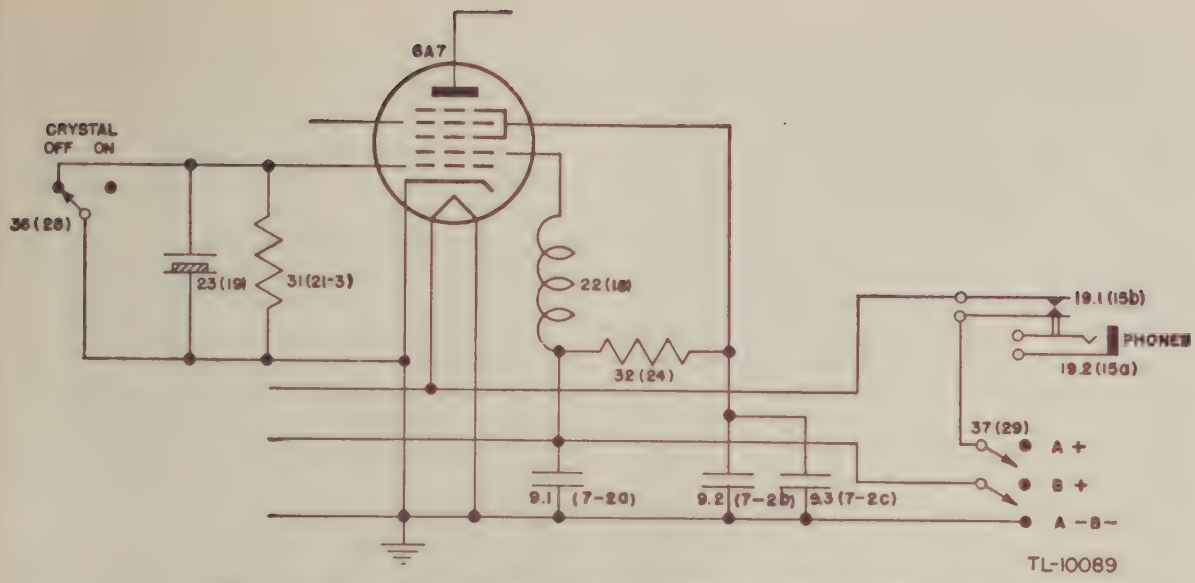


Figure 28. Frequency Meter BC-221-(1), functional diagram, crystal-oscillator circuit.

(fig. 28), which operates at a fixed frequency of 1,000 kc when CRYSTAL switch 36 (28) is placed in the ON position. The crystal circuit is removed from operation when CRYSTAL switch 36 (28) is turned to the OFF position thus placing a short circuit around the crystal. The crystal circuit is designed to generate considerable harmonic energy so that it can be used to calibrate the variable frequency oscillator at several points over its entire range. The necessary plate circuit impedance is built up across an untuned inductance 22 (18) housed in a bakelite case of rugged construction and thoroughly sealed against moisture. Resistor 31 (21-3) shunted across crystal 23 (19) serves as the crystal oscillator grid leak. Resistor 32 (24) supplies voltage to the screen grid of the type 6A7 tube. Capacitors 9.2 (7-2b) and 9.3 (7-2c) in parallel bypass the screen grid to ground. Capacitor 9.1 (7-2a) is a bypass capacitance across the plate voltage supply. For further details of the crystal oscillator circuit, see paragraph 22.

NOTE. In Frequency Meter Set SCR-211-(1) the variable frequency oscillator is in operation when the power switch is on, regardless of the position of the crystal switch. Therefore, the crystal oscillator cannot be used as described in paragraph 22b (1) (*b*), because of interference from the variable frequency oscillator.

53. Variable Frequency Oscillator Circuit (par. 23)

Tube VT-77 (77) is used in an electron coupled circuit as the variable frequency oscillator. (See fig. 29.)

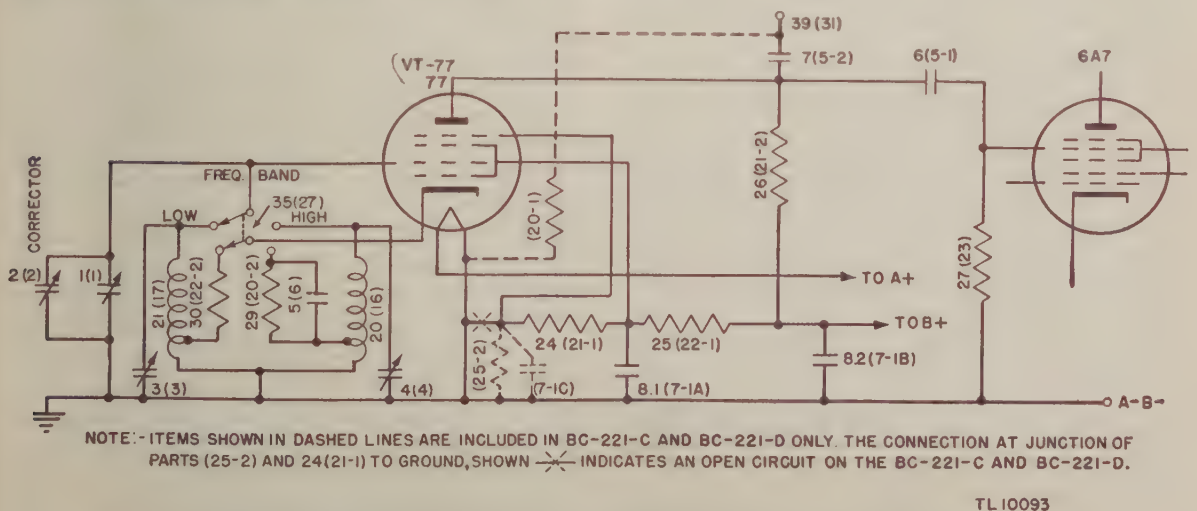


Figure 29. Frequency Meter BC-221-(1), functional diagram, variable frequency oscillator circuit.

a. Coils. The two inductors 20 (16) and 21 (17) in the tuned circuits are wound on ceramic forms and thoroughly sealed against moisture to eliminate the influence of changing atmospheric conditions on the stability of the meter. The active terminals of these coils are connected across the terminals of main tuning capacitor 1 (1) by means of band selector (FREQ. BAND LOW-HIGH) switch 35 (27). Each coil and the tuning capacitor, together with other capacitors mentioned below, constitute the resonant circuit that determines the output frequency. The correct operating bias on the control grid of the oscillator tube is provided by resistor 30 (22-2) in the tube cathode lead in the LOW frequency position of the band selector switch, and by the capacitor and resistor combination 5 (6) and 29 (20–2) in the cathode lead in the HIGH position. The position of the cathode taps on the coils serves to control the amount of feedback in the oscillator circuit. Resistor 26 (21–2) is the oscillator tube plate circuit load, and the voltage developed across it is coupled to the detector-converter tube 6A7 through capacitor 6 (5–1), or to antenna plug 39 (31) through capacitor 7 (5–2). Resistors 25 (22–1) and 24 (21–1) comprise a voltage divider network for obtaining screen grid voltage in the oscillator tube. In the BC–221–C and BC–221–D, a third resistor (25–2) is added to the network in order to supply a small positive voltage to the suppressor grid of the oscillator tube. Part No. 8.1 (7–1a) is the screen grid bypass capacitor to ground. Capacitor (7–1c) in the BC–221–C and BC–221–D bypasses the suppressor grid to ground. Capacitor 8.2 (7–1b) bypasses the plate voltage supply. Resistor (20–1) in the BC–221–C and BC–221–D provides a shunt from the antenna post to ground.

b. Band Selector Switch. Swith 35 (27) is a double-throw, double-pole switch with all contacts mounted on ceramic plates. To minimize abnormal capacitive effects, all contacts are made as small as possible and are of the self-aligning, self-wiping type. The switch has a heavy detent which locates the rotor plate accurately in either the LOW or HIGH frequency position.

c. Corrector Control. Capacitor 2 (2), the CORRECTOR control with a range of 2 micromicrofarads ($2\mu\mu f$), enables the operator to control the variable capacitance of the tuned circuit in order to compensate for slight changes in the circuit. (See par. 35g.)

d. Trimming Capacitors. The trimming capacitors are parts 3 (3) and 4 (4). These capacitors are adjusted at the factory to build up the fixed capacitance of the LOW and HIGH frequency circuits to the exact values called for by the design of the variable tuning capacitor.

Caution: Do not tamper with these trimmer capacitor settings. To do so will throw the meter completely off calibration.

e. Oscillator Function. (1) The variable frequency oscillator is in operation at all times when the POWER switch is in the ON position and when a headset is plugged into the PHONES jack, regardless of the position of the CRYSTAL OFF-ON switch. (See figs. 31 and 32.)

(2) At the CRYSTAL ON position, the output of oscillator Tube VT–77 is applied to one of the grids of detector-converter tube 6A7 where it is mixed with the output frequency of the crystal circuit. The result is a frequency equal to the difference of the two and is used to adjust the frequency of the oscillator with the CORRECTOR control.

(3) At the CRYSTAL OFF position, the variable frequency oscillator is in operation, while the crystal oscillator is not. If the antenna is in position, the frequency meter may be used to receive or send any frequency in its range; that is, it may be used as a radio receiver or transmitter.

54. Detector Tube Circuit

It has been stated that the three inner elements of the type 6A7 tube are used in the crystal oscillator circuit. The remaining elements of this tube (comprising the control grid, screen grid, and plate) are used as a high gain screen grid detector to which, by tube structure, the crystal oscillator is electronically coupled. (See fig. 30.) The r-f voltage, developed across load resistor 26 (21–2) in the plate output circuit of the variable frequency oscillator, is coupled to the control grid of this detector through a small fixed capacitor 6 (5–1). Antenna plug 39 (31), mounted on the chassis, is also coupled to the control grid of the detector, through coupling capacitors 7 (5–2) and 6 (5–1) in series. Resistor 27 (23) is the detector tube grid leak. As a result of these couplings to the control grid, the detector mixes the variable frequency oscillator output with the fundamental and successive harmonics of the crystal oscillator, when the CRYSTAL switch is in the ON position and with the radio transmitter frequency to be measured, when the CRYSTAL switch is in the OFF position. When the CRYSTAL switch is thrown to the OFF position, crystal 23 (19) and its shunt resistor 31 (21–3) are short-circuited and the inner grid

of the type 6A7 tube is grounded. (See fig. 28.) By reference to figures 29 and 30, it can be seen that antenna plug 39 (31) is also coupled directly to the variable frequency oscillator output through capacitor 7 (5–2) alone. Thus, antenna plug 39 (31) serves the dual purpose of a detector input terminal for the measurement of frequencies of external origin and of a variable frequency oscillator output terminal for use in calibrating receivers. When the unit is employed for the latter purpose, a minimum of 2,000 microvolts of radio frequency energy will be available between the antenna terminal and ground (the chassis) at any frequency within the calibrated range.

high-impedance (15,000 ohms) or low-impedance (2,500 ohms) headsets may be used without any change-over adjustments being necessary.

56. Power Supply Circuit (figs. 31 and 32) All power required for the operation of the meter is introduced through battery terminal board 44 (36). The common negative filament and negative plate battery leads are connected to the middle terminal which is grounded to the chassis. A fabricated wiring harness is provided for intercell and filament battery to terminal board connections. Section 37.2 (29a) of the POWER switch closes the positive 6-volt supply terminal (A+) to the vacuum tube filaments

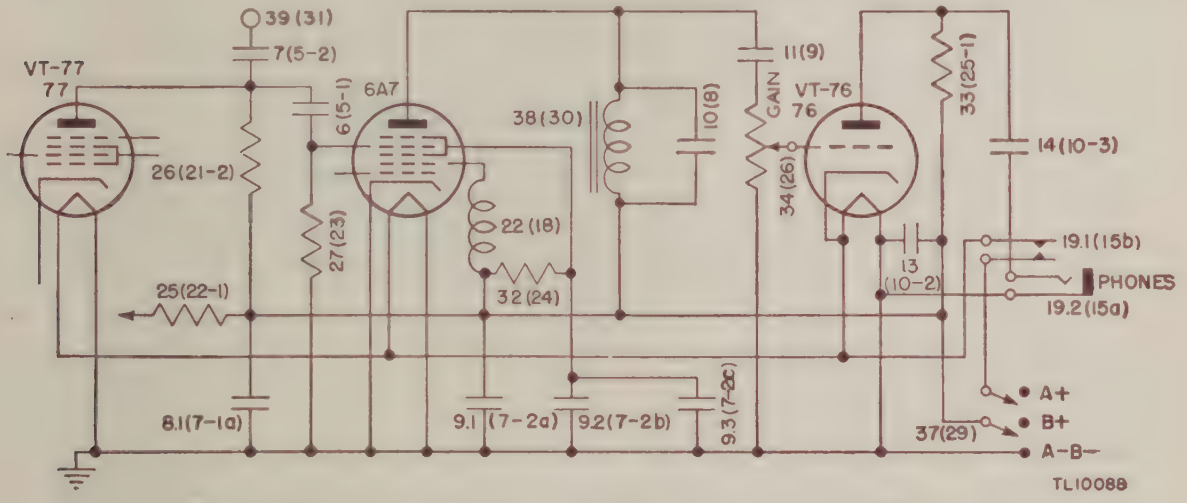


Figure 30. Frequency Meter BC–221–(1), functional diagram, detector and audio-amplifier circuits.

55. Audio-Amplifying Circuit (par. 25) The detector plate works into an audio-frequency choke coil 38 (30), which is bypassed by capacitor 10 (8) to reduce the response to high frequencies. The beat-frequency voltages built up across the choke coil are coupled through capacitor 11 (9) and GAIN control potentiometer 34 (26) to the grid of Tube VT–76 (76). The grid of Tube VT–76 returns to ground through potentiometer 34 (26), the desired bias voltage being obtained by connecting the cathode to the positive side of the filament. The plate of Tube VT–76 returns to the positive plate supply voltage through load resistor 33 (25–1), the latter being bypassed to ground through capacitor 13 (10–2). The plate of Tube VT-76 is also coupled to PHONES jack 19.2 (15a) through capacitor 14 (10–3), so that no d-c voltage will be present in the output circuit. The characteristics of the output circuit are such that either

through auxiliary switch 19.1 (15b) when the headset plug is inserted into the PHONES jack; and section 37.1 (29b) connects the positive 135-volt terminal (B+) to all plate and screen circuits. Since the door covering the control panel cannot be closed with the headset plug in place, the *A* batteries cannot be discharged when the meter is put away, even though the POWER switch may be left ON. A voltage divider method of obtaining screen grid voltage on the variable frequency oscillator tube is used, however, and, if the meter is put away with the POWER switch ON, a constant load will be present on the *B* batteries. Rapid deterioration of the *B* batteries might take place under certain conditions and cause severe damage, by chemical action, to the battery compartment of the frequency meter.

Caution: The power switch must be turned off before taking the SCR–211–A, SCR–211–C, or SCR–211–D out of service.

Section IV. MAINTENANCE

57. General

For all details of field maintenance, see paragraphs 26, 27, and 28.

Section V. SUPPLEMENTARY DATA

58. Tabular List of Maintenance Parts

a. Frequency Meter BC–221–A.

Note. Order maintenance parts by stock number, name, and description.

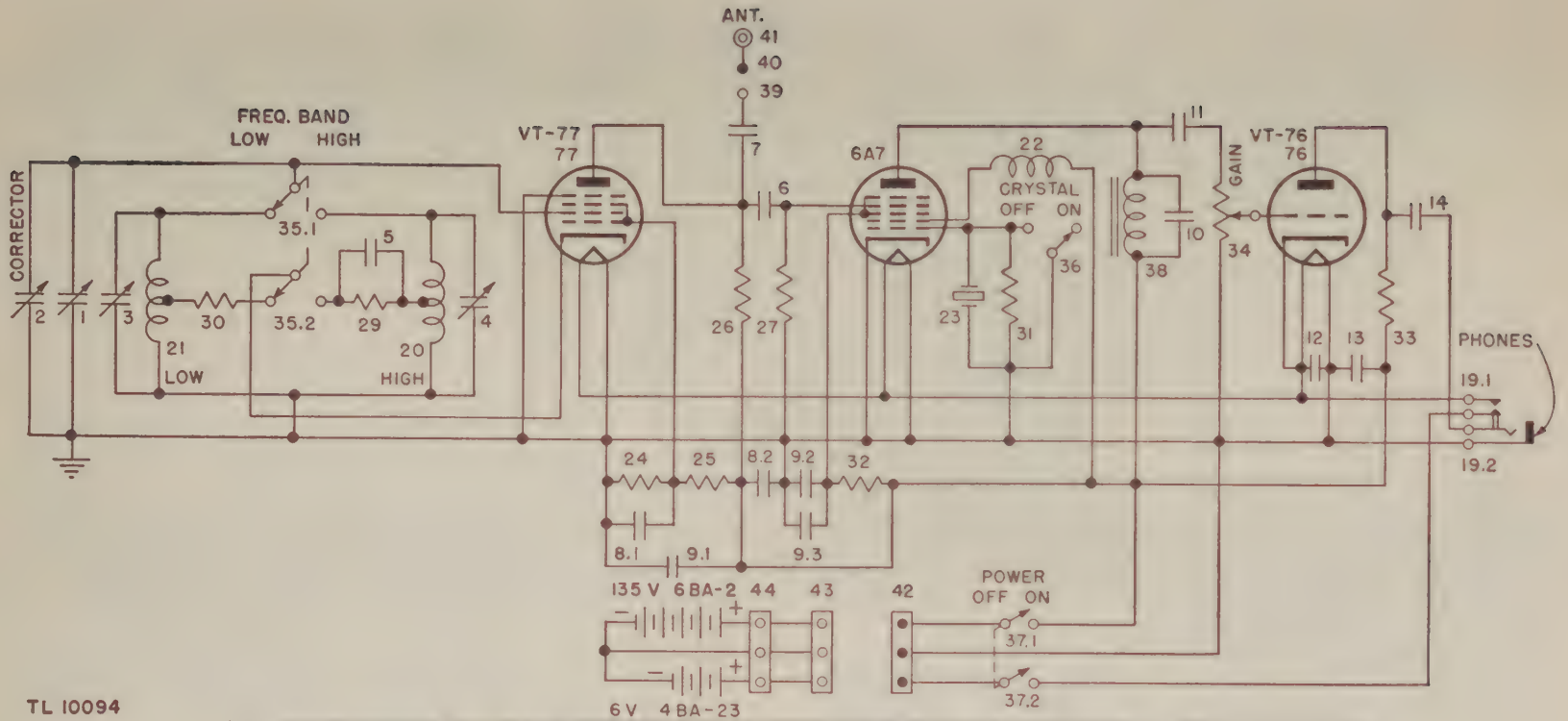
Reference No. symbol	Signal Corps stock No.	Name of part and description	Quan. per equip.	Lowest maint. echelon
	2Z481A	BAG: BG–81–A; carrying	1	3d
	2Z551–160	BAG: BG–160–(&)/S; available for amphibious operations	1	Orgn stock
	3A2	BATTERY: BA2; 22.5=v	6	3d
	3A23	BATTERY: BA23; 1.5=v	4	3d
	3E1605–6.5	CORD: CD–605; 6½=ft; 2=cond.; PL–55 at one end; Transformer C–410 at other.	1	3d
	3E1874	CORD: CD–874; 6½=ft; 2=cond.; PL–55 on one end; JB–47 on other end.	1	3d
	2B830(&)	HEADSET: HS–30–(&); component HEADSET: HS–30–(&); repair parts	1	Orgn stock
	2B1300	INSERT: M–300	2	Orgn stock
	2Z9019A	STRAP: ST–19–A	1	3d

b. Frequency Meters BC–221–C and BC–221–D.

Note. Order maintenance parts by stock number, name, and description.

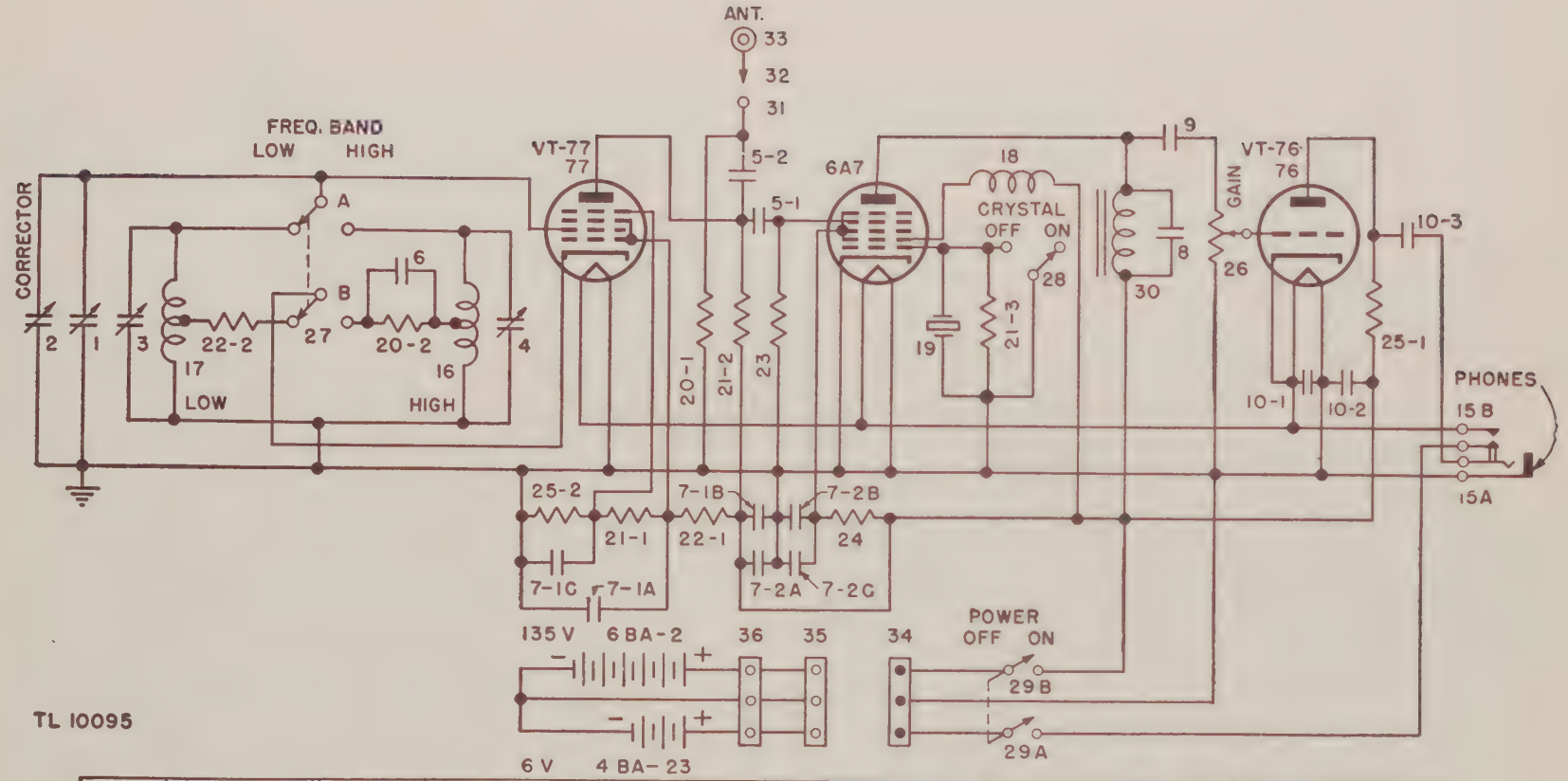
Reference No. symbol	Signal Corps stock No.	Name of part and description	Quantity per equip.	Lowest maint. echelon
	2Z481C	BAG: BG–81–C; carrying	1*	3d
	2Z481D	BAG: BG–81–D; carrying	1*	
	2Z551–160	BAG: BG–160–(&)/S; available for amphibious operations	1	Orgn stock
	3A2	BATTERY: BA2; 22.5=v	6	3d
	3A23	BATTERY: BA23; 1.5=v	4	3d
	3E1605–6.5	CORD: CD–605; 6½=ft; 2=cond.; PL–55 at one end; Transformer C–410 at the other	1	3d
	3E1874	CORD: CD–874; 6½=ft; 2=cond.; PL–55 on one end; JB–47 on other end	1	3d
	2B830(&)	HEADSET: HS–30–(&); component HEADSET: HS–30–(&); repair parts.	1	Orgn stock
	2B1300	INSERT: M–300	2	Orgn stock
	2Z9019A	STRAP: ST–19–A	1	3d

* Only one Bag BG–81–C or BG–81–D is furnished per equipment.



REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	150 μμf	10	.001 μf	22	1.7 MILLIHY	32	30,000 OHM	41	BINDING POST
2	2 μμf	11	.02 μf	23	CRYSTAL	33	15,000 OHM	42	POWER PLUGS
3	10 μμf	12	0.5 μf	24	50,000 OHM	34	500,000 OHM	43	POWER JACKS
4	10 μμf	13	0.5 μf	25	10,000 OHM	35.1&.2	SWITCH	44	BATTERY TERM
5	500 μμf	14	2.0 μf	26	50,000 OHM	36	SWITCH		
6	25 μμf	19.1	FIL. SWITCH	27	1 MEGOHM	37.1&.2	SWITCH		
7	50 μμf	19.2	JACK	29	5,000 OHM	38	600 HENRYS		
8.1&.2	0.1 μf	20	38.5 MICROHY	30	10,000 OHM	39	ANT. PLUG		
9.1,.2,.3	0.1 μf	21	10.1 MILLIHY	31	50,000 OHM	40	ANT. JACK		

Figure 31. Frequency Meter BC-221-A, schematic diagram.



REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	150 μμf	7–1C	0.1 μf	15B	FIL. SWITCH	23	1 MEGOHM	31	ANT. PLUG
2	2 μμf	7–2A	0.1 μf	16	HIGH FREQ. COIL	24	30,000 OHM	32	CONTACT SPRING
3	10 μμf	7–2B	0.1 μf	17	LOW FREQ. COIL	25–1&2	15,000 OHM	33	BINDING POST
4	10 μμf	7–2C	0.1 μf	18	1.7 MILLIHY	26	0.5 MEGOHM	34	POWER PLUGS
5–1&2	10 μμf	8	.001 μf	19	CRYSTAL	27	SWITCH	35	POWER JACKS
6	250 μμf	9	.02 μf	20–1&2	5,000 OHM	28	SWITCH	36	BATTERY TERM
7–1A	0.1 μf	10–1,2,3	0.5 μf	21–1,2,3	50,000 OHM	29	SWITCH		
7–1B	0.1 μf	15A	JACK	22–1&2	10,000 OHM	30	450 HENRYS		

Figure 32. Frequency Meters BC–221–C and BC–221–D, schematic diagram.

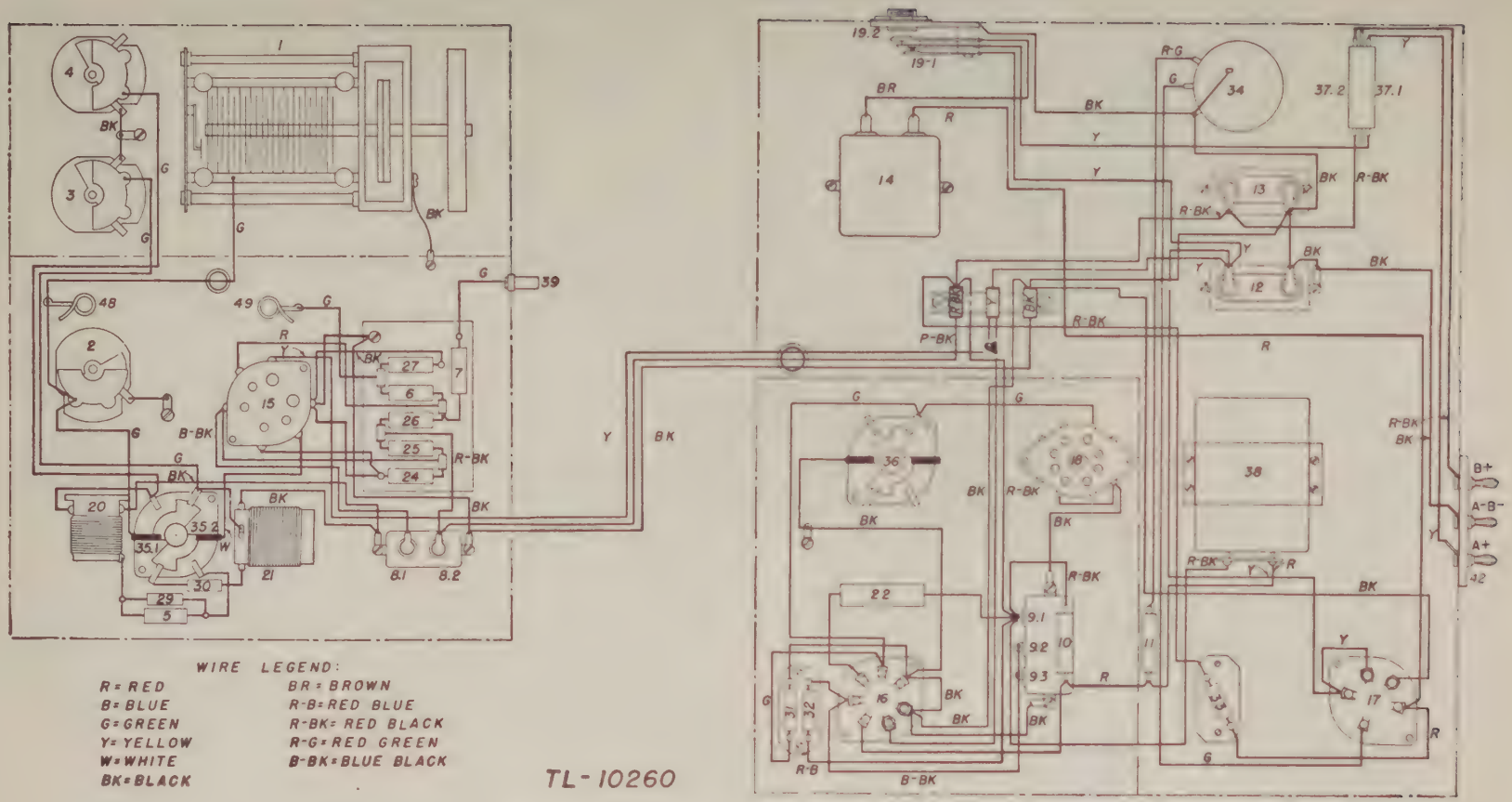


Figure 33. Frequency Meter BC-221-A, chassis wiring diagram.

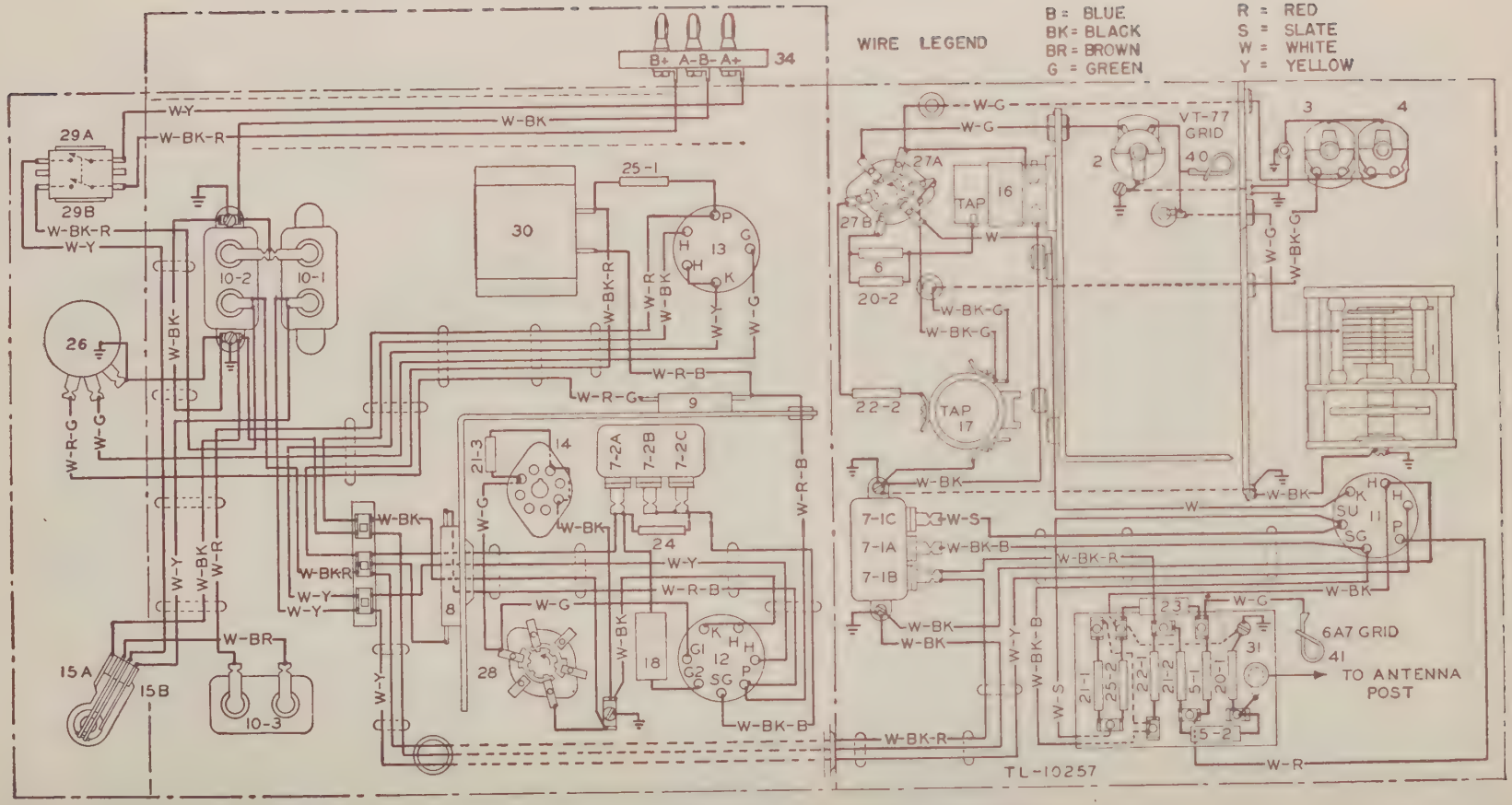


Figure 34. Frequency Meters BC–221–C and BC–221–D, chassis wiring diagram.

CHAPTER 3

FREQUENCY METER SETS SCR–211–B AND SCR—211–Q

Section I. DESCRIPTION

59. General

Frequency Meter Sets SCR–211–B and SCR–211–Q have been manufactured by the Allen D. Cardwell Mfg. Corporation on several orders. These two models are essentially alike in all important details, but there are several important differences that are specified in this chapter. Early models of the SCR–211–B differ from the later models of the same set, and all of the SCR–211–B models differ slightly from the SCR–211–Q. The later models of the SCR–211–B contain a revision in the antenna circuit, the value of the grid leak of the detector-converter tube, and in the crystal circuit. Part numbers on the schematic diagrams differ also, and in some cases, the electrical values of the parts vary. For this reason three schematic diagrams are printed here; two for the two types of the SCR–211–B and one for the SCR–211–Q. For further general information see paragraph 2. The symbol (2) as used throughout this chapter refers to the SCR–211–B or SCR–211–Q.

60. Components

Each Frequency Meter Set SCR–211–(2) includes the following component units:

Quantity	Component
1.....	Frequency Meter BC–221–(2) includes:
	1 Crystal Unit DC–9–(2) (in operating position).
	1 Crystal Unit DC–9–(2) (spare, mounted on chassis).[1]
	1 Calibration Book MC–177–(2).
	1 Calibration Book MC–177–B (spare, untyped, in chassis compartment).[2]
	1 Battery Tray.
	1 Wrench for Bristo No. 6 setscrew (chassis compartment).
2.....	Tube VT–167, Type 6K8 (one in use, one spare).
4.....	Tube VT–116, Type 6SJ7 (two in use, two spare).
1.....	Strap ST–19–A.
1.....	Bag BG–81–(2).
1.....	Instruction book or technical manual for Frequency Meter Set SCR–211–(2).
1.....	Additional spare set of vacuum tubes (one each); (supplied in bulk)[2]

[1] Not supplied with BC–221–Q nor with some orders of the BC–221–B.
[2] Not supplied with SCR–211–Q.

61. Additional Equipment Required

The following equipment, not furnished with the orders, is required to complete each Frequency Meter Set SCR–211–(2):

Quantity	Article
1.....	Headset P–18 or P–20, or Headset HS–30–(&) with Cord CD–605.
6.....	Batteries BA–2.
4.....	Batteries BA–23.

62. Total Weight

Frequency Meter Set SCR–211–(2), complete and ready for service, weighs approximately 38 pounds. For typical dimensions, see figure 26.

63. Power Consumption

All power required for the operation of this equipment is supplied by the batteries listed in paragraph 61. The current drains at the specified voltage limits are as follows:

Filaments: 5.4 to 6.0 volts, 0.86 to 0.91 ampere.
Plates, etc.: 121.5 to 135.0 volts, 0.0145 to 0.017 ampere.

These values are typical for operation with the operation switch in the CHECK position, under which condition maximum plate current is drawn.

64. Controls

When the snap latch is released and the front cover lowered, the control panel and calibration book are exposed. There are six operating controls (fig. 4):

a. Two PHONES jacks allow observations by two persons at the same time; for example, student and instructor. A headset must be plugged into one of the jacks before the meter can be set in operation because of the series filament supply switches built into the jacks.

b. The GAIN control is a volume control used to adjust the input voltage to the audio-amplifier tube, and in turn the level of sound in the headset.

c. The OFF-CRYSTAL-OPERATE-CHECK control is the operation switch of Frequency Meter BC–221–(2). In the OFF position, both the *A* and *B* battery circuits are open. In the CRYSTAL position, the *A* battery circuit is closed to the series filament supply switches which are built into the PHONES jacks, while the *B* battery circuit is closed to all tubes with the exception of the variable frequency oscillator. In the OPERATE position, the *A* battery circuit is closed as above, and the *B* battery circuit is closed to all tubes with the exception of the crystal oscillator portion of the detector-converter tube. In the CHECK position, the *A* battery circuit remains closed, while the *B* battery circuit is closed to all tubes. The CHECK position places maximum load on the batteries. Since there are no voltage divider arrangements in this circuit, the meter can be taken out of service by removing the plug from the PHONES jack, regardless of the position of the operation switch.

d. The FREQ. BAND LOW-HIGH switch permits the selection of the appropriate band of the variable frequency oscillator as indicated by the frequency being checked or calibrated.

e. The frequency of the variable frequency oscillator is controlled by setting the dial labeled DIAL UNITS which is graduated into one hundred divisions. One revolution of the DIAL UNITS dial moves the DIAL HUNDREDS dial one division. (See par. 11.)

f. The CORRECTOR knob controls a small variable capacitor across the variable frequency oscillator tuned circuit, and is used to compensate for small changes in capacity brought about by temperature, humidity, and mechanical changes. It is adjusted at each CRYSTAL CHECK POINT to make the calibration of the instrument as accurate as possible over that part of the scale centered at a given CRYSTAL CHECK POINT and extending halfway to the next higher and next lower CRYSTAL CHECK POINTS.

65. Vacuum Tubes

The vacuum tubes used in the Frequency Meter Set SCR–211–(2) are shown in the following tabulation:

Reference	Function	Signal Corps type nomenclature	Commercial equivalent	Base
VT–116.....	Variable frequency oscillator.	VT–116.....	6SJ7*.....	Octal
VT–167.....	Crystal oscillator and detector.	VT–167.....	6K8.....	Octal
VT–116.....	Audio-frequency amplifier.	VT–116.....	6S J7.....	Octal

* Frequency Meter Set SCR–211–Q up to approximate serial No. 2500 was originally supplied with Tube VT-116-B (6SJ7Y). This is practically the same as Tube VT-116 (6SJ7) but has a special electrically low-loss base. After serial No. 2500 Tube VT-116 (6SJ7) was supplied and the chassis tube stamping was modified with a rubber stamp which indicates that either VT-116-B or VT-116 may be used.

Section II.

INSTALLATION AND OPERATION

66. Initial Procedure (par. 7)

If the second set of spare tubes, in the case of the SCR–211–B, is stored in the battery compartment, remove it when inspecting the equipment and place it in stock.

67. Installation of Batteries (par. 8)

Remove the frequency meter chassis from the cabinet when installing the batteries.

a. Location of Battery Tray. At the rear of the cabinet, two small catches lock the door of the battery compartment. To release them, revolve them a half turn (in a counterclockwise direction) with a coin or screw driver. The battery tray is inside this compartment. (See fig. 36.) It can be pulled out by the ring at the top without detaching the cable. There is no need to disconnect the cable from the tray or from the meter during the battery assembly.

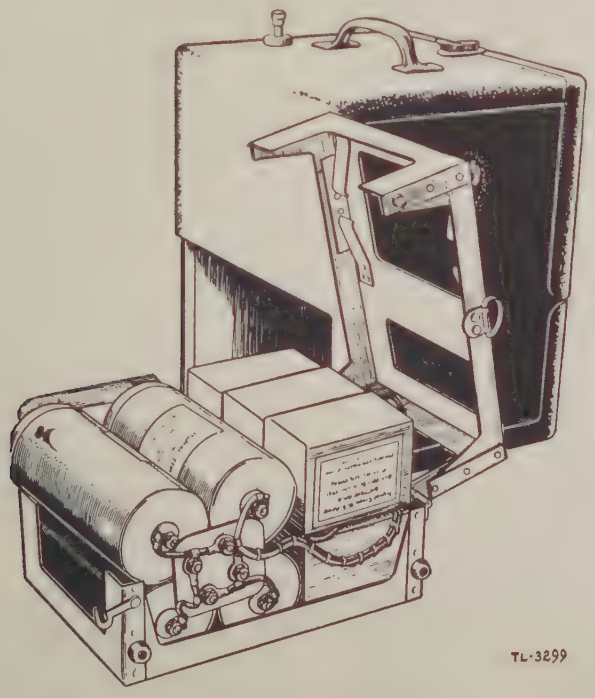


Figure 35. Frequency Meter BC–221–(2), loaded battery tray with sections separated to show construction.

b. Description of Battery Tray. The tray (fig. 35), is hinged at one end and held in place by two hooks near the opposite end. When the hooks are released, the tray should open easily and spread out to allow changing of the batteries. Place the opened battery tray so that the ring used to remove it faces the operator. Three of the six *B* Batteries BA–2 are placed in the right-hand section of the tray (the lower half), against the terminal board which is secured to the tray.

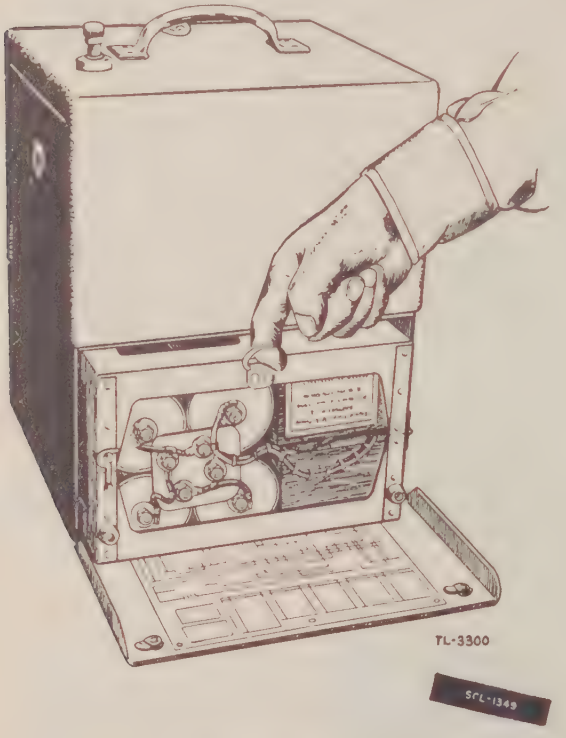


Figure 36. Frequency Meter BC–221–(2), removal of battery tray from frequency meter using finger ring at top.

c. Wiring Batteries in Tray. (1) The wires from each of the positive and negative battery terminals are brought through similarly marked holes on the terminal board and fastened by screws. The red wires are positive; the black, negative. Place the other three *B* batteries on top of those already wired and connect them in turn through the six holes at the top of the board. Remove the nuts on the binding posts of the *A* Batteries BA–23 and lay the batteries in the tray so that their outside (negative) terminals pass through holes in the small terminal plate. (See fig. 9.) With these connections completed, all the *A* batteries are in series and their total voltage should be 6 volts. The *B* Batteries BA–2 are also in series and should give 135 volts. The *A* voltage is read between the two *A* terminals on the terminal board and the *B* voltage between the two *B* terminals. After replacing the frequency meter chassis, check the battery installation as in paragraph 8d.

(2) Close the tray, lock its two hooks, and place in the battery compartment with the pull ring facing out.

d. Wiring Tray to Meter. The battery tray is connected to the meter proper by means of a black rubber-covered cable of three wires. Each wire is terminated at the battery tray with marked terminal lugs. Connect the wires as follows:

Green positive wire to the B+ screw.
White positive wire to the A+ screw.
Black negative wire to the A–B–screw.

Close the battery compartment door. The meter is now ready for use.

68. Antenna (par. 9)

69. Headset (par. 10)

The headset is usually kept in the compartment at the front of the cabinet marked "Open Cover for Headset." (See fig. 20.) The Plug PL–55 or Plug PL–125 of the Headset P–18 or P–20 must be inserted in one of the PHONES jacks before the meter will operate.

70. Preparation for Use

a. To start the meter, insert the headset plug into a PHONES jack and then turn the OFF-CRYSTAL-OPERATE-CHECK switch away from its OFF position to any one of the other three available positions. The instrument will operate only when both of these steps have been taken.

b. After starting the set by the method described above, allow the vacuum tube filaments to heat for 15 to 20 minutes.

c. In order to test for normal operating conditions, set the operation switch knob at CHECK. While rotating the DIAL UNITS dial, listen in the headset for tones of increasing and decreasing pitch. These different tones are produced by the changing variable oscillator frequency beating with the various crystal harmonics. The presence of these tones indicates normal operation.

71. Reading the Dial (par. 11)

72. Calibration Book MC–177–(2) (par. 12)

73. Operating Circuits (par. 13)

74. Zero Beat Detection (par. 14)

75. Correction in Calibration (par. 15)

The information given there applies exactly to Frequency Meter BC–221–(2).

76. Crystal Check Points (par. 16)

77. Frequency Measurements (par. 17)

The proper position of the operation switch of the BC–221–(2) is OPERATE for making frequency measurements as described in paragraph 17.

78. Precautions During Operation (par. 18)

79. Adjustments for Field Upkeep (par. 19)

Section III. FUNCTIONING OF PARTS

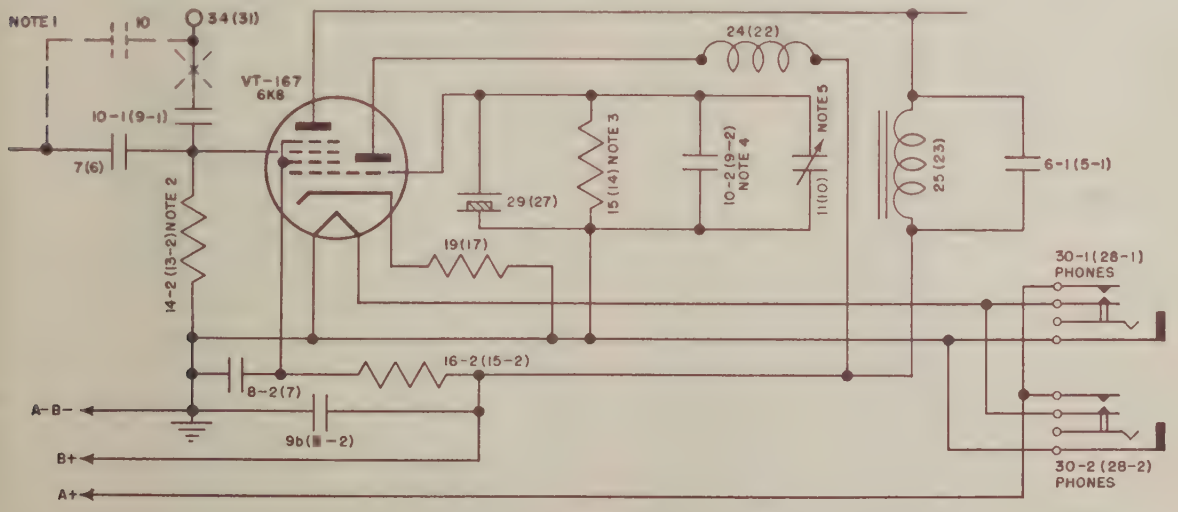
80. General

As stated in paragraph 59 there are a number of differences between early and late models of the BC–221–B, and between the BC–221–B and the BC–221–Q. In order to describe all three types at once a special numbering system is employed in the descriptions to follow in this section. The numbers in parentheses apply to the BC–221–Q, while the numbers out of parentheses apply to the later models of the BC–221–B. The few references needed in the case of the early models of the BC–221–B are provided for by footnotes on the functional diagrams. As an example of the numbering system, the designation 24 (22) means part No. 24 of the BC–221–B and part No. 22 of the BC–221–Q. For further details see figures 40, 41, and 42.

81. Circuit Components (par. 21)

82. Crystal Circuit

The crystal circuit uses the triode section of Tube VT–167 (6K8) shown in figure 37. The oscillator operates at the fixed frequency of 1,000 kc when the operation switch 27 (26) is placed in the CRYSTAL or CHECK position. The operation switch controls the crystal oscillator by opening or closing its plate voltage circuit. The oscillator circuit is designed to generate considerable harmonic energy so that it can be used to calibrate the variable frequency oscillator at several points over its entire range, as well as to supply whole multiples of 1,000 kc for the calibration of receivers and similar equipment. The necessary plate circuit impedance is built up across an untuned inductance 24 (22), inclosed in a metal can. Resistor 15 (14), part No. 15–2 in the early model BC–221–B, is the oscillator grid leak and works in conjunction with the tube cathode resistor 19 (17). The variable capacitor 11 (10) is connected across the crystal



NOTE 1:–CONNECTION SHOWN DASHED AND OPEN CIRCUIT SHOWN —×— APPLIES TO EARLY MODEL OF BC–221–B
NOTE 2:–PART NO. 15–1 IN EARLY MODEL OF BC–221–B
NOTE 3:–PART NO. 15–2 IN EARLY MODEL OF BC–221–B
NOTE 4:–PART NO. 11 IN EARLY MODEL OF BC–221–B
NOTE 5:–OMITTED IN EARLY MODEL OF BC–221–B

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Figure 37 Frequency Meter BC–221–(2), functional diagram, crystal-oscillator circuit.

29 (27) for the purpose of adjusting the frequency of the crystal to a closer point than can be economically obtained by grinding alone. When the frequency meters are adjusted during manufacture, the variable capacitor is set up to produce a frequency of 1,000 kc ± 5 cycles at 20° centigrade. The fixed capacitor 10–2 (9–2), shunted across the crystal, minimizes any change in fundamental frequency due to small changes in the crystal capacitance. It should be noted, that part No. 11 (10) was omitted from the early BC–221–B, and that part No. 10–2 (9–2) was part No. 11. Further reference to figure 37 shows that the output of the crystal oscillator is electron coupled to the antenna through the No. 3 grid of the hexode section of Tube VT–167 and the capacitor 10–1 (9–1). Note further, that in the case of the early BC–221–B, this connection was made by capacitors 7 (6) and 10 in series. For further details on the crystal oscillator, see paragraph 22.

83. Variable Frequency Oscillator Circuit

(par. 23)

Tube VT–116 (6SJ7) is used in an electron coupled circuit as the variable frequency oscillator. (See fig. 38.)

a. Coils. The two inductors 22 (20) and 23 (21), in the tuned circuits, are entirely inclosed in individual ceramic containers to prevent mechanical injury and to eliminate the influence of changing atmospheric conditions on the stability of the meter. (See fig. 23.) The active terminals of these coils are connected across the terminals of the main tuning capacitor 1 (1) by means of the band selector (FREQ. BAND LOW-HIGH) switch 26 (25). Each coil and the tuning capacitor, together with other capacitors mentioned below, constitute the resonant circuit that determines the output frequency. The correct operating bias on the control grid of the oscillator tube is provided by the capacitor and resistor combination 5 (4) and 14–1 (13–1) (part No. 14 in the early BC–221–B) which connects to a tap on either coil through the band selector switch 26 (25). The frequency of oscillation is made relatively independent of variations in tube characteristics when the grid connection is tapped down an appreciable distance from the high-potential end of the coil. The resistors 18 (12) and 21–1 (19–1), which carry little current, are connected in series with the taps, and serve to stabilize the operation of the oscillator circuit by suppressing undersirable oscillations. These resistors are mounted inside of the coil containers and seldom require replacement. The second coil tap, located near the grounded end of each coil, and connected to the cathode of the oscillator tube through another set of contacts on switch 26 (25), serves to control the amount of feedback in the oscillator circuit. Resistor 17 (16) is the oscillator tube plate circuit load, and the voltage developed across it is coupled to detector-converter Tube VT–167 (6K8) through capacitor 7 (6), or to the antenna through capacitors 7 (6) and 10–1 (9–1) in series. (Note that in the case of the early BC–221–B the oscillator plate is coupled to the detector tube by capacitor 7 (6) and to the antenna by capacitor 10.) Part 16–1 (15–1) is the screen grid dropping resistor, and part 6–2 (5–2) is the screen grid bypass capacitor to ground. Capacitor 9a (8–1) bypasses the plate voltage supply.

b. Band Selector Switch. Switch 26 (25) is a double-throw, triple-pole switch with all contacts mounted on ceramic plates. To minimize abnormal capacitive effects, all contacts are made as small as possible and are of the self-aligning, self-wiping type with dual contacts. The switch has a heavy detent which accurately locates the rotor plate in either the LOW or HIGH frequency position.

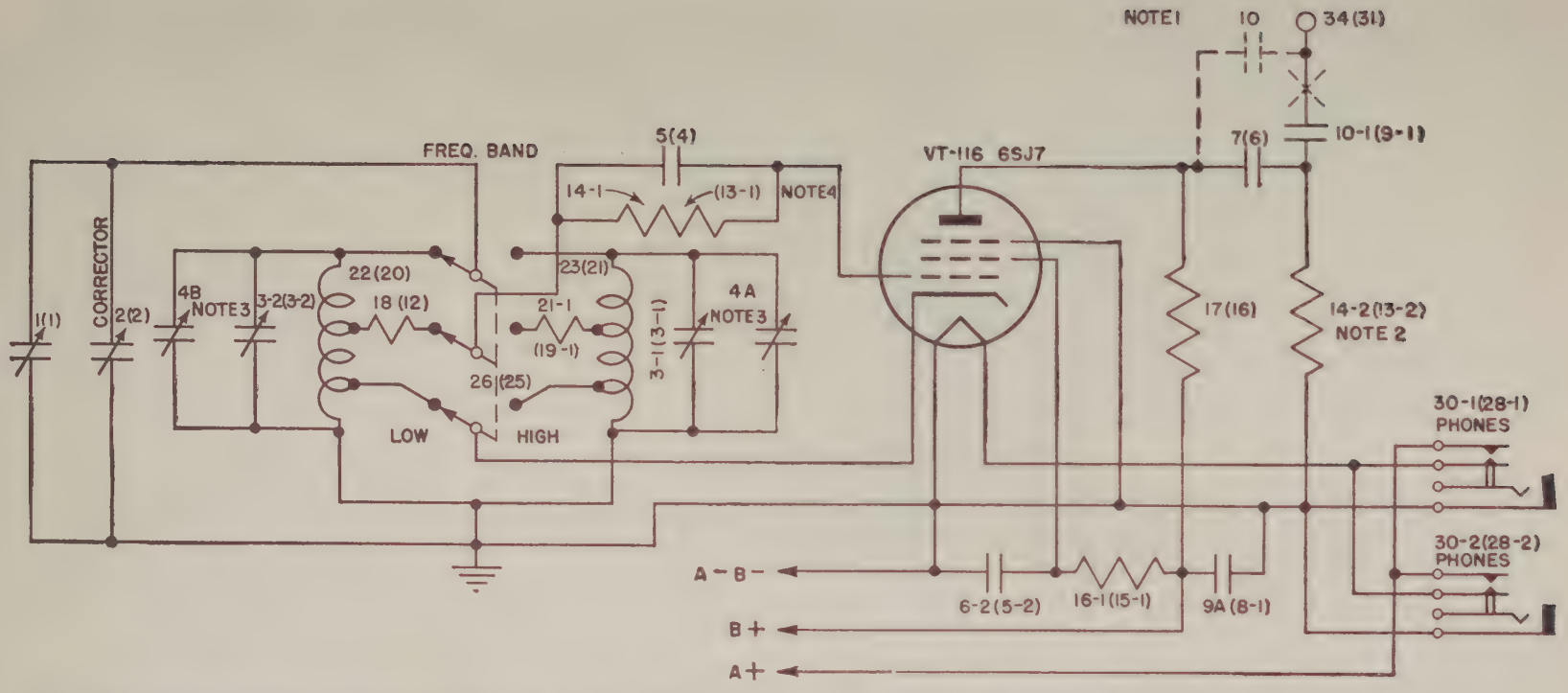
c. Corrector Control. Capacitor 2 (2), the CORRECTOR control, with a range of 1 micromicrofarad (1$\mu\mu$f), enables the operator to control the variable capacitance of the tuned circuit in order to compensate for slight changes in the circuit. (See par. 64f.)

d. Trimming Capacitors. The trimming capacitors are parts 3–1 (3–1) and 3–2 (3–2). These capacitors are adjusted at the factory to build up the fixed capacitance of the LOW and HIGH frequency circuits to the exact values called for by the design of the variable tuning capacitor.

Caution: Do not tamper with these trimmer capacitor settings. To do so may throw the meter completely off calibration. These capacitors are equipped with thermal compensator capacitors (part Nos. 4a and 4b in the BC–221–B) which prevent frequency drifts due to temperature changes. These compensators are built into the trimming capacitors on the BC–221–Q and do not carry separate part numbers.

e. Oscillator Function. (1) The variable frequency oscillator is in operation at the CHECK and OPERATE positions of the operation switch 27 (26). (See figs. 40, 41, and 42.)

(2) At the CHECK position, the output of oscillator Tube VT–116 (6SJ7) is applied to



NOTE 1: CONNECTION SHOWN DASHED AND OPEN CIRCUIT SHOWN —✕— APPLIES TO EARLY MODEL OF BC-221-B.
NOTE 2: PART NO. 15-1 IN EARLY MODEL OF BC-221-B.
NOTE 3: PART NOS. 4A AND 4B ARE INTEGRAL PARTS OF 3-1 AND 3-2 IN THE BC-221-Q.
NOTE 4: PART NO. 14 IN EARLY MODEL OF BC-221-B.

TL-10091

Figure 38. Frequency Meter BC-221-(2), functional diagram, variable frequency oscillator circuit.

one of the grids of detector-converter Tube VT–167 (6K8) where it is mixed with the output frequency of the crystal circuit. The result is a frequency equal to the difference of the two, and is used to adjust the frequency of the oscillator by means of the CORRECTOR control.

(3) At the OPERATE position, the variable frequency oscillator is in operation, while the crystal oscillator is not. If the antenna is in position, the frequency meter may be used to receive or send any frequency in its range, that is, it may be used as a radio receiver or transmitter.

84. Detector Tube Circuit

It has been stated that the triode section of Tube VT–167 (6K8) is used in the crystal-oscillator circuit. The remaining hexode section of this tube, of which the No. 1 grid is tied to the control grid of the triode section, is used as a high gain screen grid detector with hexode grid No. 3 acting as the control grid. The joint action of grids No. 1 and 3 produces electron coupling of the signals on the two grids. (See fig. 39.) Resistor 14–2 (13–2), part No. 15–1 in the early model of the BC–221–B, is the detector tube grid leak. Resistor 16–2 (15–2) supplies voltage to the screen grid of Tube VT–167 (6K8). Capacitor 8–2 (7) bypasses the screen grid to ground. Capacitor 9b (8–2) is a bypass capacitance across the plate voltage. The r-f voltage developed across the load resistor 17 (16) in the plate output circuit of the variable frequency oscillator is coupled to the No. 3 grid of this detector through a small fixed capacitor 7 (6). The antenna plug or clip 34 (31) is also coupled to the No. 3 grid through the coupling capacitor 10–1 (9–1). (Note that in the early BC–221–B the antenna clip 34 (31) is coupled to the No. 3 grid through capacitors 10 and 7 (6) in series.) As a result of these couplings to the control grid, the detector mixes the variable frequency oscillator output with the fundamental and successive harmonics of the crystal oscillator when the operation switch 27 (26) is in the CHECK position, and with the radio transmitter frequency to be measured when the switch is in the OPERATE position. By reference to figures 38 and 39, it can be seen that the antenna plug or clip 34 (31) is also coupled to the variable frequency oscillator output through capacitors 10–1 (9–1) and 7 (6) in series (coupled directly through capacitor 10 in the early model of the BC–221–B). Thus, the antenna plug 34 (31) serves the dual purpose of a detector input terminal for the measurement of frequencies of external origin and of a variable frequency oscillator output terminal for use in calibrating receivers. When the unit is employed for the latter purpose, a minimum of 2,000 microvolts of radio frequency energy will be available between the antenna terminal and ground (the chassis) at any frequency within the calibrated range.

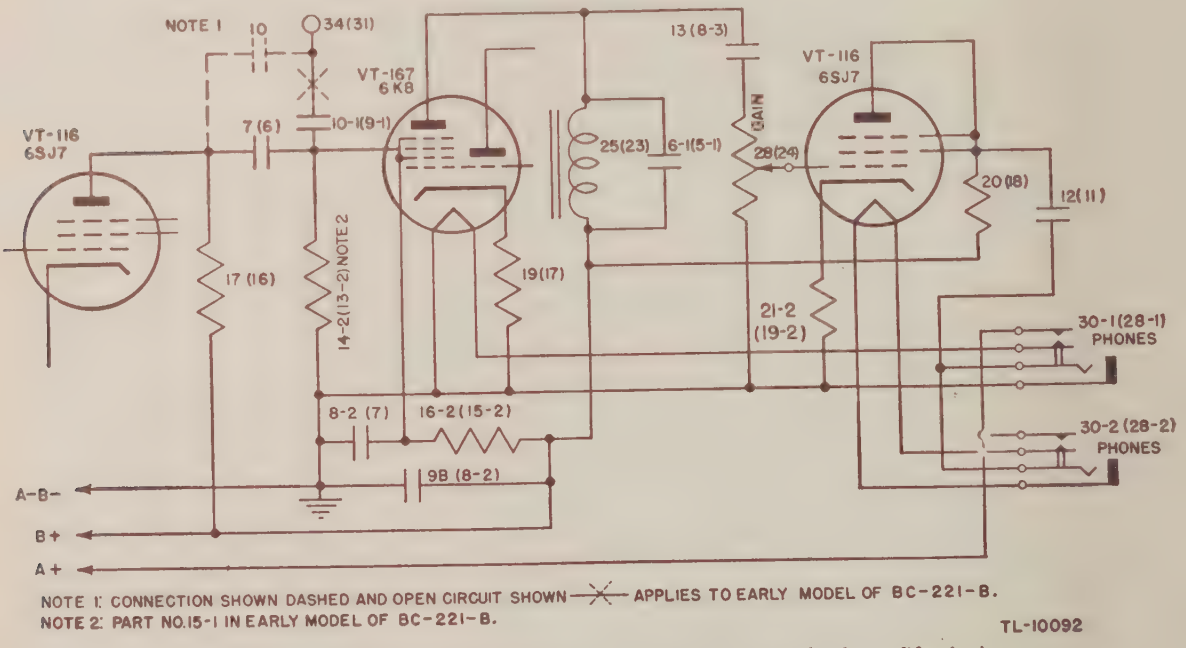


Figure 39. Frequency Meter BC–221–(2), functional diagram, detector and audio-amplifier circuits.

85. Audio-Amplifying Circuit (par. 25)

The detector plate works into an audio-frequency choke coil 25 (23), which is bypassed by the capacitor 6–1 (5–1) to reduce the response to high frequencies. The beat frequency voltages built up across the choke coil are coupled through capacitor 13 (8–3) and the GAIN control potentiometer 28 (24) to the grid of Tube VT–116 (6SJ7) connected as a triode. The grid of Tube VT–116 returns to ground through the potentiometer 28 (24), and the necessary grid bias voltage is obtained by means of the cathode dropping resistor 21–2 (19–2). The plate (tied to the suppressor and screen grids) of Tube VT–116 returns to the positive plate supply voltage through the plate load resistor 20 (18). The plate of this tube is coupled also to the PHONES jacks 30–1 (28–1) and 30–2 (28–2) through capacitor 12 (11), so that no d-c voltage will be present in the output circuit. The characteristics of the output circuit are such that either high-impedance (15,000 ohms) or low-impedance (2,500 ohms) headsets may be used without any change-over adjustments being necessary.

86. Power Supply Circuit (figs. 40, 41, and 42)

All power required for the operation of the meter is introduced through the battery terminal board 32 (29), located at the end of the battery cable. The common negative filament and negative plate battery leads are connected to the left-hand plug, facing the chassis compartment, which is grounded to the chassis. The operation switch 27 (26) closes both the positive 6-volt supply (A+) and the positive 135-volt supply (B+) as described previously in paragraph 64c. The positive 6-volt supply (A+) is closed to the vacuum tube filaments through the auxiliary switches on the PHONES jacks 30–1 (28–1) or 30–2 (28–2), when a headset plug is inserted in one of the jacks. Since the door covering the control panel cannot be closed with the headset plug in place, the *A* and *B* batteries cannot be discharged even though the operation switch is left in an active position when the meter is removed from service.

Section IV. MAINTENANCE

87. General

For all details of field maintenance see paragraphs 26, 27 and 28.

Section V. SUPPLEMENTARY DATA

88. Tabular List of Maintenance Parts

a. Frequency Meter BC–221–B.

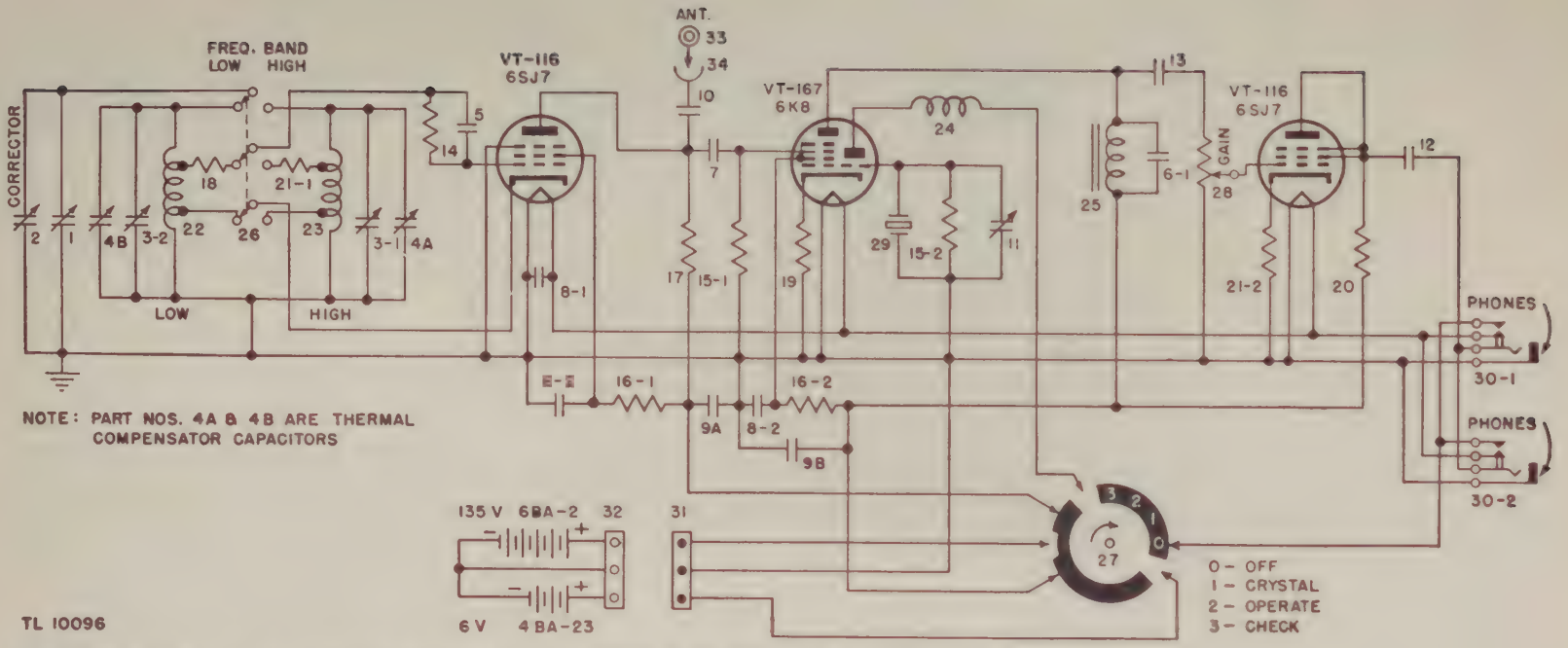
Note. Order maintenance parts by stock number, name, and description.

Ref. No. symbol	Signal Corps stock No.	Name of part and description	Quan. per equip.	Lowest maint. echelon
	2Z481B.	BAG: BG–81–B; carrying.....	1...	3d
	2Z551–160 ..	BAG: BG–160–(&)/S; available for amphibious operations.	1..	Orgn stock
	3A2.....	BATTERY: BA2; 22.5=v.....	6...	3d
	3A23.....	BATTERY: BA23; 1.5=v.....	4...	3d
	3E1605–6.5	CORD: CD–605; 6½=ft; 2=cond.; PL–55 at one end; Transformer C–410 at other.	1...	3d
	3E1874.....	CORD: CD–874; 6½=ft; 2=cond.; PL–55 on one end; JB–47 on other end.	1...	3d
	2B830(&)....	HEADSET: HS–30–(&); components HEADSET: HS–30–(&); repair parts } ...	1...	Orgn stock
	2B1300.....	INSERT: M–300.....	2...	Orgn stock
	2Z9019A	STRAP: ST–19–A.....	1...	3d

b. FREQUENCY METER BC–221–Q.

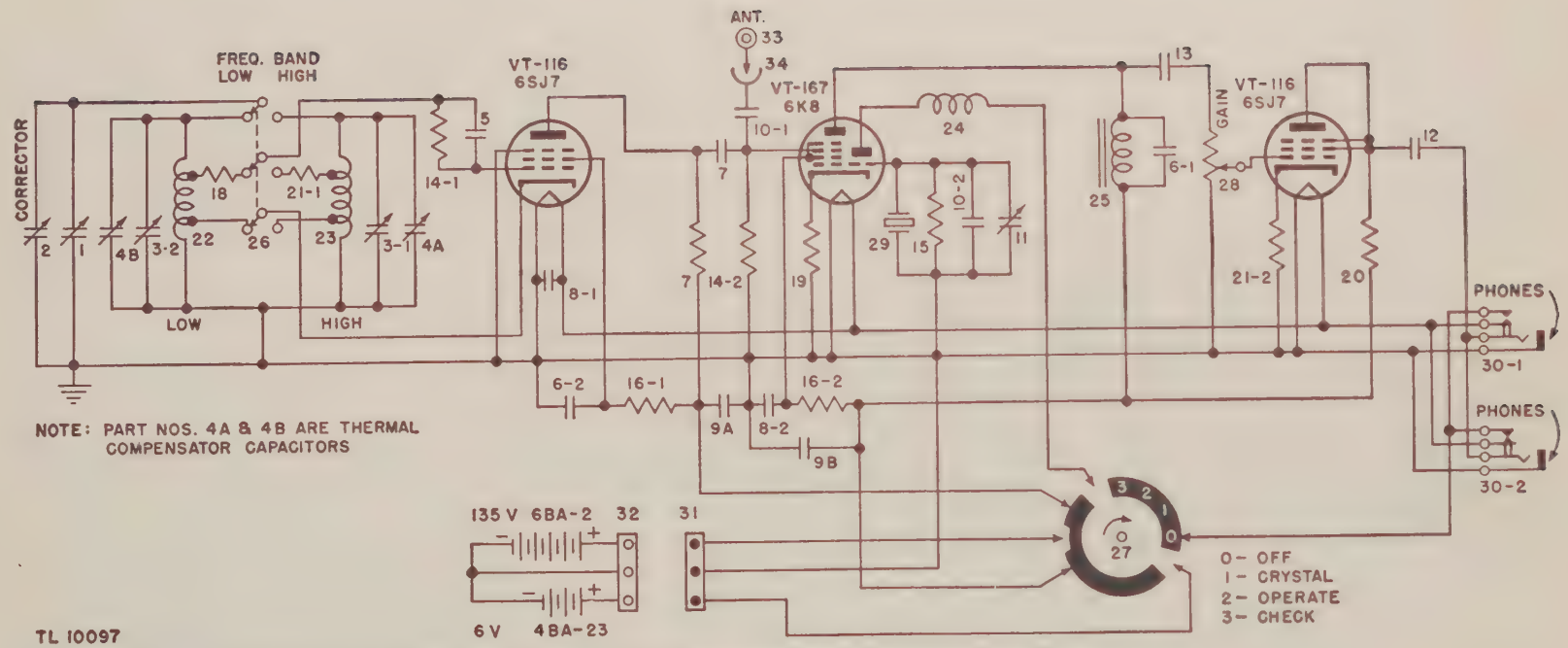
NOTE. Order maintenance parts by stock number, name, and description.

Ref. No. symbol	Signal Corps stock No.	Name of part and description	Quan. per equip.	Lowest maint. echelon
	2Z481Q.....	BAG: BG–81–Q; carrying	1...	3d
	2Z551–160...	BAG: BG–160–(&)/S; available for amphibious operations.	1...	Orgn stock
	3A2.....	BATTERY: BA2; 22.5-v.....	6...	3d
	3A23.....	BATTERY: BA23; 1.5-v.....	4...	3d
	3E1605–6.5..	CORD: CD–605; 6½-ft; 2-cond.; PL–55 at one end; Transformer C–410 at other.	1...	3d
	3E1874.....	CORD: CD–874; 6½-ft; 2-cond.; PL–55 on one end; JB–47 on other end.	1...	3d
	2B830(&)....	HEADSET: HS–30–(&); component HEADSET: HS–30–(&); repair parts } ...	1...	Orgn stock
	2B1300.....	INSERT: M-300.....	2...	Orgn stock
	2Z9019A	STRAP: ST–19–A.....	1...	3d



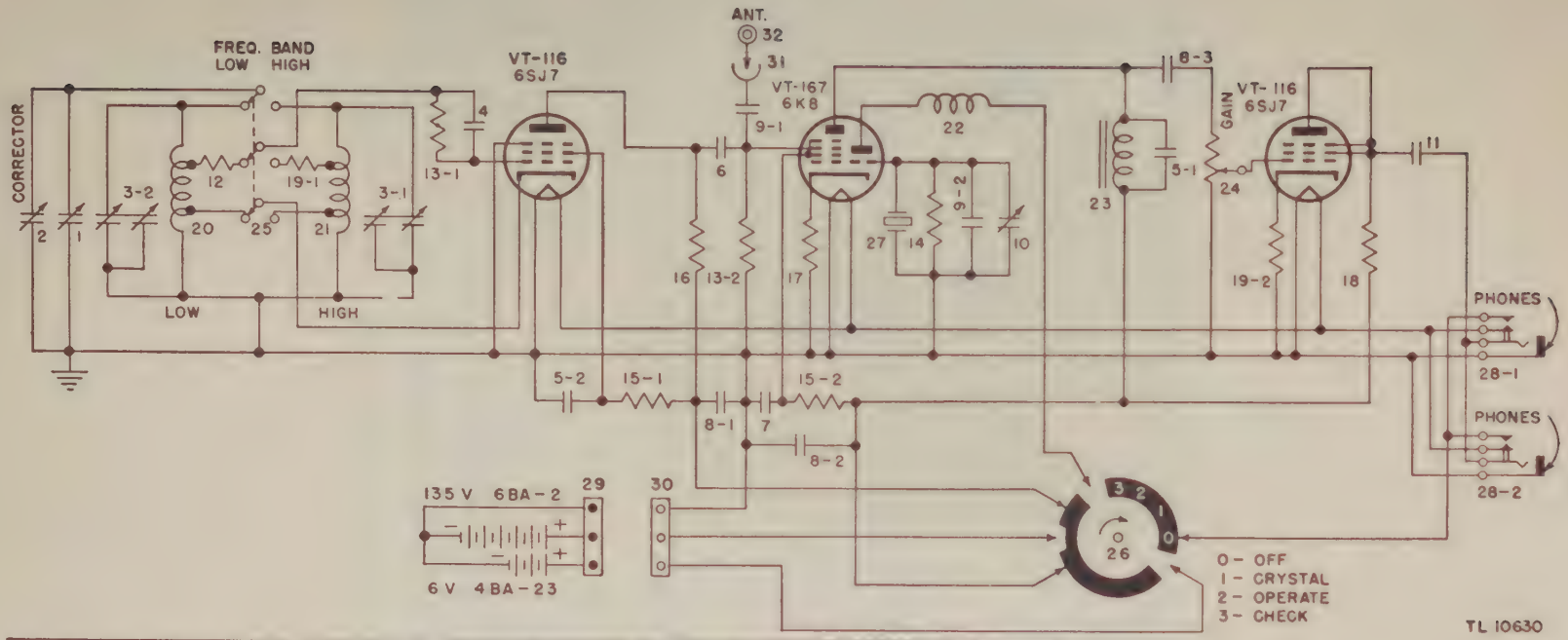
REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	235 μμf	8–1&2	.001 μf	15–1&2	1 MEGOHM	22	6.5 MILLIHY	29	CRYSTAL
2	1 μμf	9A&B	0.1 μf	16–1&2	8,750 OHM	23	24.8 MICROHY	30–1&2	JACK
3–1&2	25 μμf	10	8 μμf	17	50,000 OHM	24	735 MICROHY	31	POWER PLUGS
4A&B	1μμf	11	25 μμf	18	4,500 OHM	25	300 HENRYS	32	POWER JACKS
5	100 μμf	12	2 μf	19	75 OHM	26	SWITCH	33	BINDING POST
6–1&2	.002 μf	13	0.25 μf	20	12,500 OHM	27	SWITCH	34	ANT. CLIP
7	50 μμf	14	150,000 OHM	21–1&2	350 OHM	28	0.5 MEGOHM		

Figure 40. Frequency Meter BC–221–B (early model), schematic diagram.



REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	235 μμf	8–1&2	.001 μf	15	1 MEGOHM	22	6.5 MILLIHY	29	CRYSTAL
2	1μμf	9A&B	.01 μf	16–1&2	8,750 OHM	23	24.8 MICROHY	30–1&2	JACK
3–1&2	25 μμf	10–1&2	12 μμf	17	50,000 OHM	24	735 MICROHY	31	POWER PLUGS
4A&B	1 μμf	11	11 μμf	18	4,500 OHM	25	300 HENRYS	32	POWER JACKS
5	100 μμf	12	2 μf	19	75 OHM	26	SWITCH	33	BINDING POST
6–1&2	.002 μf	13	.25 μf	20	12,500 OHM	27	SWITCH	34	ANT. POST
7	.50 μμf	14–1&2	150,000 OHM	21–1&2	350 OHM	28	0.5 MEGOHM		

Figure 41. Frequency Meter BC–221–B (late model), schematic diagram.



REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	220 μμf	8-1,2,3	.05 μf	15-1&2	8,750 OHM	22	735 MICROHY	29	POWER PLUGS
2	1 μμf	• 9-1&2	12 μμf	16	50,000 OHM	23	300 HENRYS	30	POWER JACKS
3-1&2	25 + 4 μμf	10	12 μμf	17	75 OHM	24	1 MEGOHM	31	ANT. CLIP
4	100 μμf	11	2 μf	18	12,500 OHM	25	SWITCH	32	BINDING POST
5-1&2	.002 μf	12	4,500 OHM	19-1&2	350 OHM	26	SWITCH		
6	50 μμf	13-1&2	150,000 OHM	20	6.5 MILLIHY	27	CRYSTAL		
7	.001 μf	14	1 MEGOHM	21	25 MICROHY	28-1&2	JACKS		

• REF. NO. 9-2 IS 6μμf

Figure 42. Frequency Meter BC-221-Q, schematic diagram.

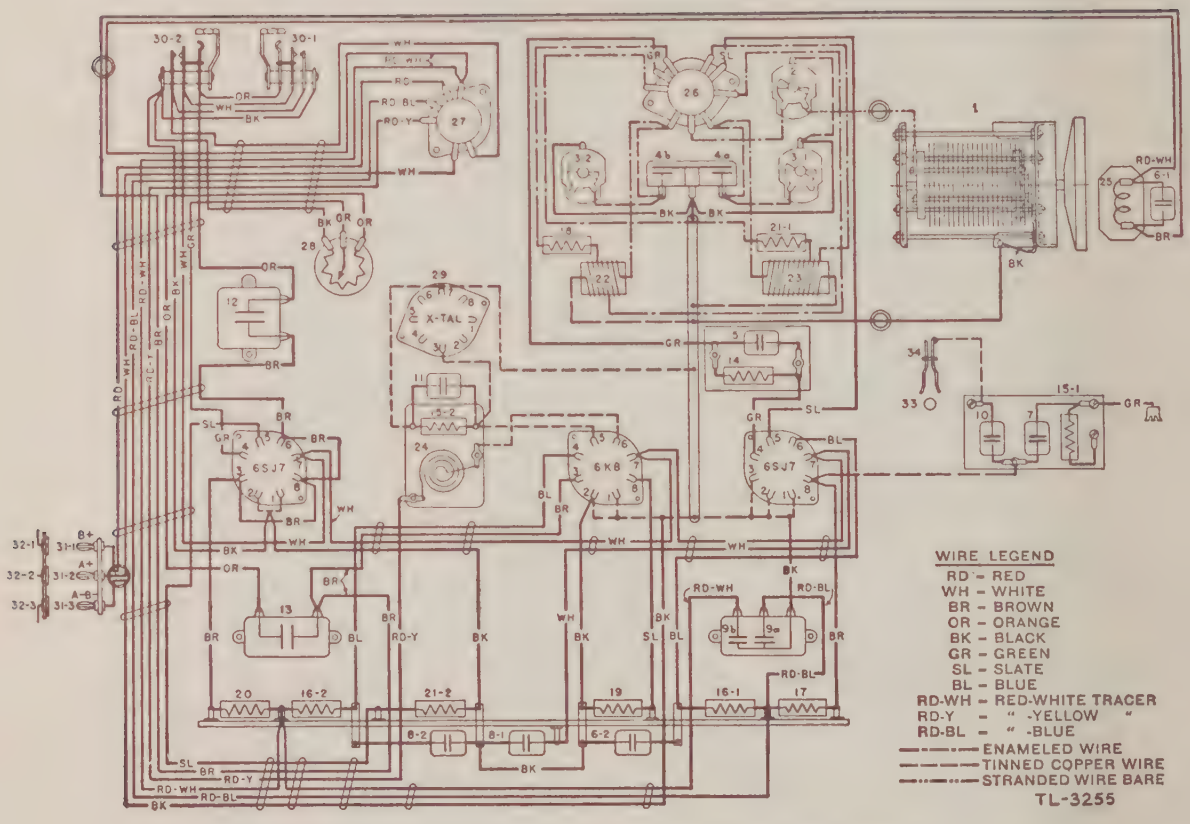


Figure 43. Frequency Meter BC–221–B (early model), chassis wiring diagram.

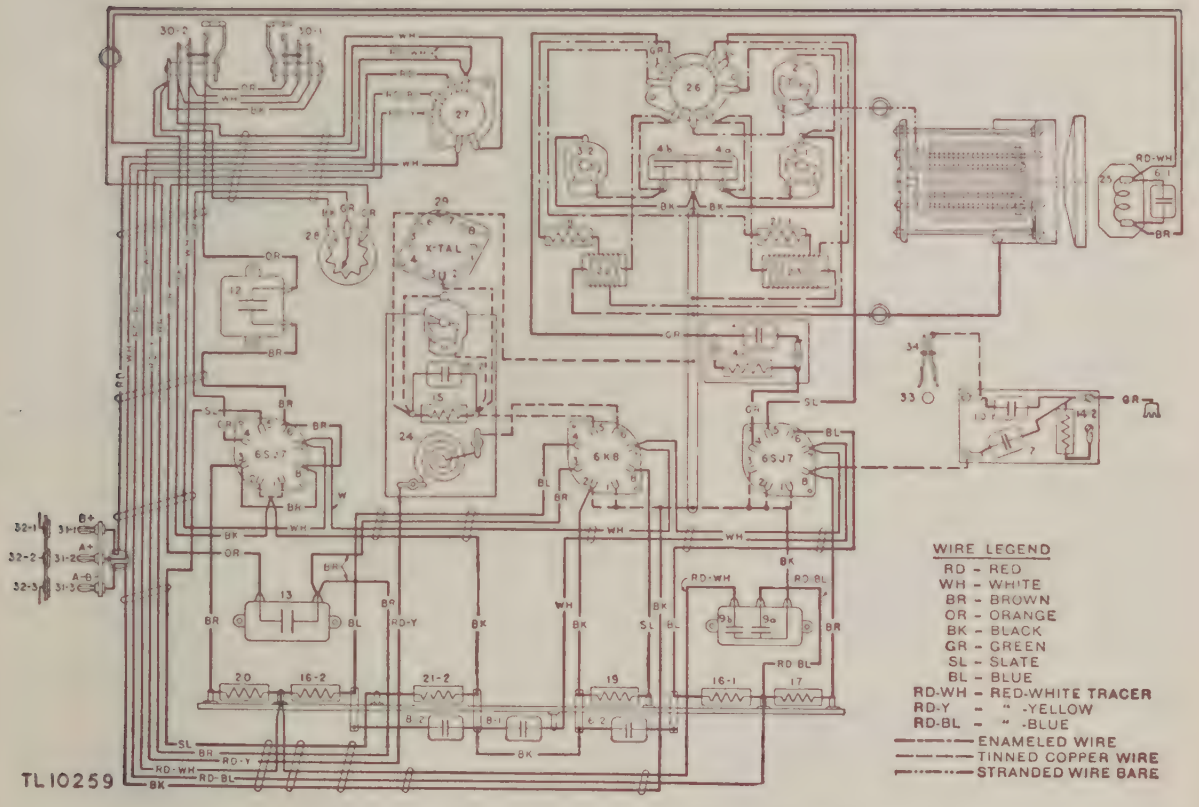


Figure 44. Frequency Meter BC–221–B (late model), chassis wiring diagram.

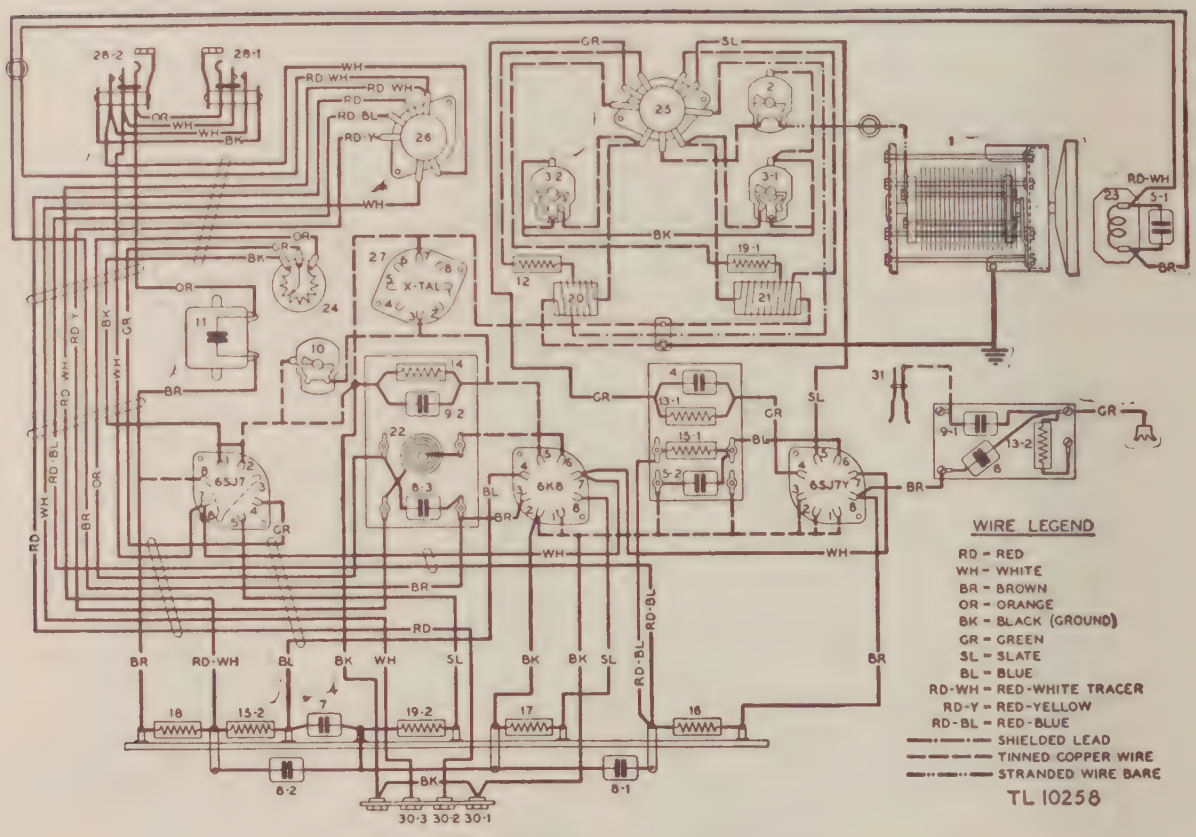


Figure 45. Frequency Meter BC–221–Q, chassis wiring diagram.

CHAPTER 4

FREQUENCY METER SET SCR–211–E

Section I. DESCRIPTION

89. General

Frequency Meter Set SCR–211–E has been manufactured by the Philco Corporation on several orders. This model is similar to the SCR–211–B and SCR–211–Q described in chapter 3, but there are enough variations in mechanical and electrical details to warrant treatment in a separate chapter. For further general information see paragraph 2.

90. Components

Each Frequency Meter Set SCR–211–E includes the following component units:

Quantity	Component
1	Frequency Meter BC–221–E includes:
	1 Crystal Unit DC–9–E (in operating position).
	1 Crystal Unit DC–9–E (spare, mounted on chassis)*.
	1 Calibration Book MC–177–E.
	1 Calibration Book MC–177–E (spare, untyped, in chassis compartment).
	1 Wrench for Bristo No. 6 setscrew (spares compartment).
	1 Wrench for Bristo No. 8 setscrew (spares compartment).
2	Tube VT–193, type 7G7 (one in use, one spare).
2	Tube VT–208, type 7B8LM (one in use, one spare).
2	Tube VT–192, type 7A4 (one in use, one spare).
1	Bag BG–81–E.
1	Instruction book for Frequency Meter Set SCR–211–E.
3	Additional spare sets of vacuum tubes (3 each of tubes VT–193, VT–208, and VT–192, supplied in bulk).

* Originally, on Order No. 2478–Chi–41, no spare DC–9–E was supplied.

91. Additional Equipment Required

The following equipment, not furnished with the orders, is required to complete each Frequency Meter Set SCR–211–E:

Quantity	Article
1	Headset P–18 or P–20.
6	Batteries BA–2.
4	Batteries BA–23.
1	Strap ST–19–A.

92. Total Weight

Frequency Meter Set SCR–211–E, complete and ready for service, weighs approximately 38 pounds. For typical dimensions, see figure 26.

93. Power Consumption

All power required for the operation of this equipment is supplied by the batteries listed in paragraph 91. The current drains under the specified conditions are approximately as follows:

Filaments: 6 bolts; 0.71 ampere.

Plates, etc.: 135 volts; 0.0079 ampere with operation switch at CRYSTAL.

0.0141 ampere with operation switch at OPERATE.*

0.0109 ampere with operation switch at CHECK.

*Contrary to the general rule covering this type of meter, the SCR–211–E places maximum load on the batteries in the OPERATE position of the operation switch.

94. Controls (par. 2e)

When the snap latch is released and the front cover lowered, the control panel and calibration book are exposed. There are six operating controls. (See fig. 4.)

a. Two PHONES jacks allow for observations by two persons at the same time; for example, student and instructor. A headset must be plugged into one of the jacks before the meter can be set in operation because of the series filament supply switches built into the jacks.

b. The GAIN control is a volume control used to adjust the input voltage to the audio-amplifier tube, and in turn the level of sound in the headset.

c. The OFF-CRYSTAL-CHECK control is the operation switch of the BC–221–E. In the OFF position both the *A* and *B* battery circuits are open. In the CRYSTAL position, the *A* battery circuit is closed to the series filament supply switches which are built into the PHONES jacks while the *B* battery circuit is closed to all tubes with the exception of the screen grid of the variable frequency oscillator tube which effectively keeps this oscillator from operating. In the OPERATE position, the *A* battery circuit is closed as above, and the *B* battery circuit is closed to all tubes with the exception of the crystal-oscillator portion of the detector-converter tube. In the CHECK position, the *A* battery circuit remains closed, while the *B* battery circuit is closed to all tubes. The OPERATE position places maximum load on the batteries. Since there are no voltage divider arrangements in this circuit, the meter can be taken out of service by removing the plug from the PHONES jack, regardless of the position of the operation switch.

d. The FREQ. BAND LOW-HIGH switch permits the selection of the appropriate band of operation of the variable frequency oscillator as indicated by the frequency being checked or calibrated.

e. The frequency of the variable frequency oscillator is controlled by setting the dial labeled "Dial Units" which is graduated into one hundred divisions. One revolution of the DIAL UNITS dial moves the DIAL HUNDREDS dial one division. (See par. 11.)

f. The CORRECTOR knob controls a small variable capacitor across the variable frequency oscillator tuned circuit, and is used to compensate for small changes in capacity brought about by temperature, humidity, and mechanical changes. It is adjusted at each CRYSTAL CHECK POINT to make the calibration of the instrument as accurate as possible over that part of the scale centered at a given CRYSTAL CHECK POINT and extending halfway to the next higher and next lower CRYSTAL CHECK POINTS.

95. Vacuum Tubes

The vacuum tubes used in the Frequency Meter Set SCR–211–E are shown in the following tabulation:

Reference	Function	Signal Corps type nomenclature	Commercial equivalent	Base
VT–193.....	Variable frequency oscillator.	VT–193.....	7G7.....	Loctal
VT–208.....	Crystal oscillator and detector.	VT–208.....	7B8LM...	Loctal
VT–192.....	Audio frequency amplifier.	VT–192.....	7A4.....	Loctal....

Section II.

INSTALLATION AND OPERATION

96. Initial Procedure (par. 7)

Make sure a spare set of tubes is installed in the spare parts compartment. Place additional sets of spare tubes in stock.

97. Installation of Batteries (pars. 8 and 38)

After replacing the frequency meter chassis, check the battery installation as indicated in paragraph 8d with the operation switch in the OPERATE position.

98. Antenna (par. 9)

99. Headset (par. 10)

Plug PL–55 or Plug PL–125 of the Headset P–18 or Headset P–20 must be inserted in one of the PHONES jacks before the meter will operate.

100. Preparation for Use (par. 70)

101. Reading the Dial (par. 11)

102. Calibration Book MC–177–E (par. 12)

103. Operating Circuits (par. 13)

104. Zero Beat Detection (par. 14)

105. Correction in Calibration (par. 15)

The information given there applies exactly to Frequency Meter BC–221–E.

106. Crystal Check Points (par. 16)

107. Frequency Measurements (par. 17)

The proper position of the operation switch of the BC–221–E is OPERATE for making frequency measurements as described in paragraph 17.

108. Precautions During Operation (par. 18)

109. Adjustments for Field Upkeep (par. 19)

Section III. FUNCTIONING OF PARTS

110. General

Frequency Meter BC–221–E is very similar in operation to Frequency Meters BC–221–B and BC–221–Q covered in the preceding chapter, but contains a number of differences in circuit operation.

111. Circuit Components (par. 21)

112. Crystal Circuit

The cathode, the inner grid, and anode grid of Tube VT–208 (7B8LM) constitute the active elements of a crystal-controlled triode oscillator (fig. 46) which operates at the fixed frequency of 1,000 kc when the operation switch 28 is placed in the CRYSTAL or CHECK position. The operation switch controls the crystal oscillator by opening or closing its anode grid high voltage circuit. The oscillator circuit is designed to generate considerable harmonic energy so that it can be used to calibrate the variable frequency oscillator at several points over its entire range, as well as to supply whole multiples of 1,000 kc for the calibration of receivers and similar equipment. The necessary plate (anode grid) circuit impedance is built up across an inductance 23. The capacitor 44 across the inductance 23 provides a low impedance path to ground for high order harmonics of the crystal oscillator fundamental frequency (1,000 kc) so that the cathode current corresponding to these frequencies will be increased. This increased cathode current develops a voltage across the untuned inductance 13 in the cathode circuit, this voltage being impressed upon the control grid of Tube VT–208 so that the response of the detector circuit at CRYSTAL CHECK POINTS will be increased. The fixed capacitor 6–1, shunted across the crystal 25, minimizes any change in fundamental frequency due to small changes in the crystal capacitance. The resistor 20–2, shunted across the crystal 25, is the crystal oscillator grid leak. Further reference to figure 46 shows that the output of the crystal oscillator is electron coupled to the antenna through the No. 4 grid of Tube VT–208 and the capacitor 8–1. For further details on the crystal oscillator, see paragraph 22.

113. Variable Frequency Oscillator Circuit (par. 23)

Tube VT–193 (7G7) is used in an electron coupled circuit as the variable frequency oscillator. (See fig. 47.)

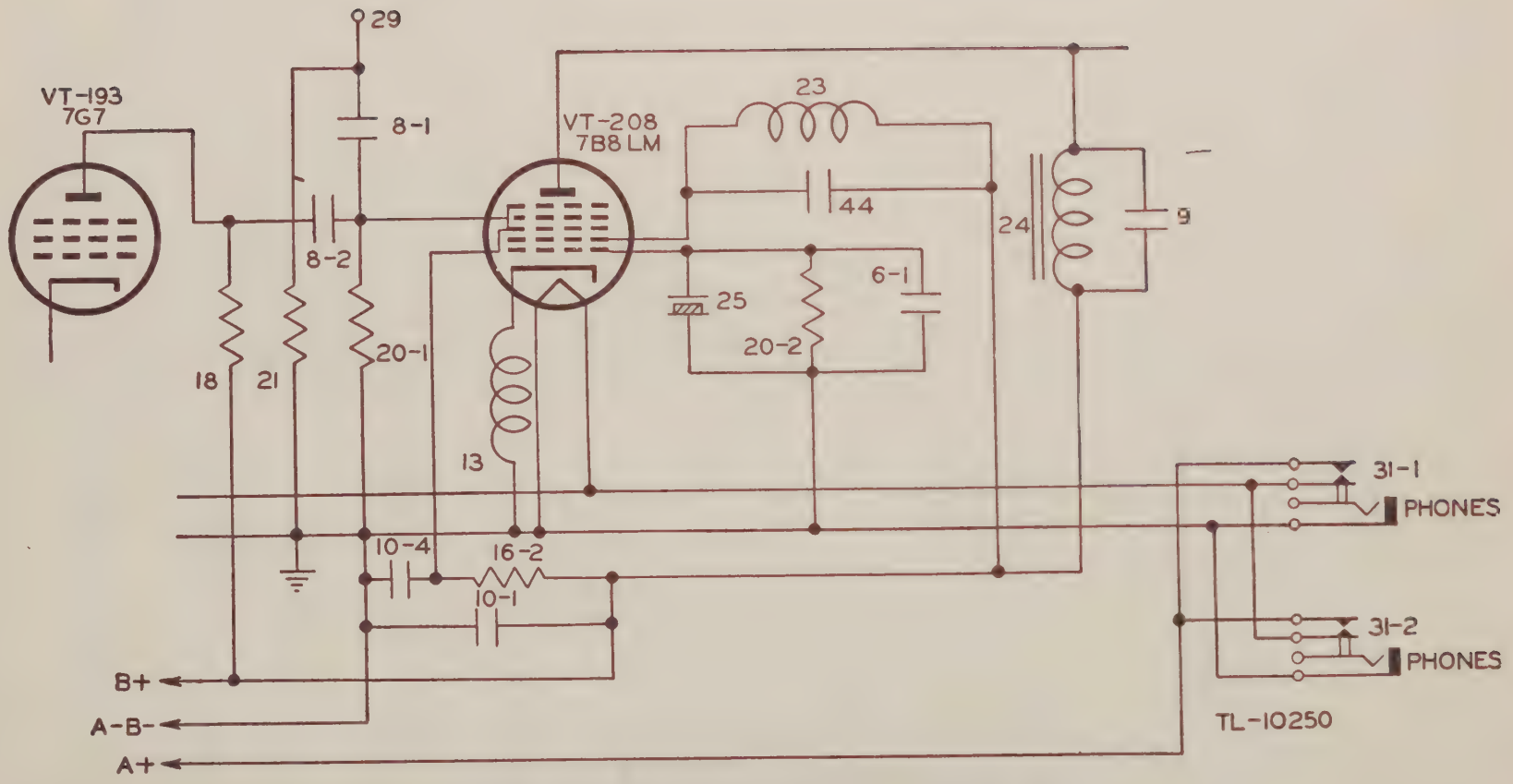


Figure 46. Frequency Meter BC-221-E, functional diagram, crystal-oscillator circuit.

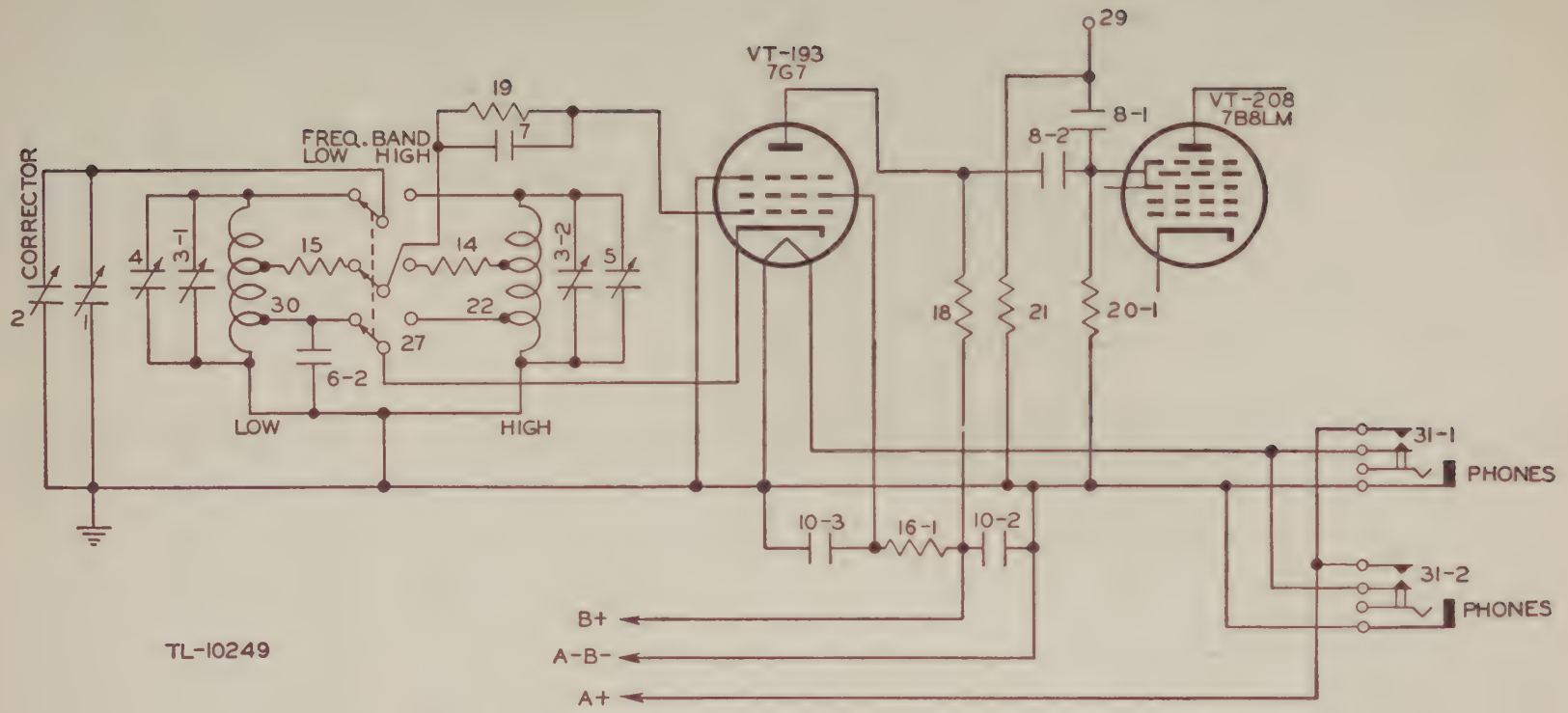


Figure 47. Frequency Meter BC-221-E, functional diagram, variable frequency oscillator circuit.

a. Coils. The two inductors 30 and 22, in the tuned circuits, are wound upon ceramic forms and coated with a special wax to eliminate the influence of changing atmospheric conditions on the stability of the meter. The active terminals of these coils are connected across the terminals of the main tuning capacitor 1 by means of the band selector (FREQ. BAND LOW-HIGH) switch 27. Each coil and the tuning capacitor, together with other capacitors mentioned below, constitute the resonant circuit that determines the output frequency. The correct bias on the control grid of the oscillator tube is provided by the capacitor and resistor combination 7 and 19 which connects to a tap on either coil through the band selector switch 27. The frequency of oscillation is made relatively independent of variations in tube characteristics when the grid connection is tapped down an appreciable distance from the high potential end of the coil. The resistors 14 and 15, which carry little current, are connected in series with the taps, and serve to stabilize the operation of the oscillator circuit by suppressing undersirable oscillations. The second coil tap, located near the grounded end of each coil, and connected to the cathode of the oscillator tube through another set of contacts on switch 27, serves to control the amount of feedback in the oscillator circuit. The capacitor 6–2, connected between the cathode tap and ground on the LOW frequency coil, prevents interaction with the HIGH frequency coil when the selector switch 27 is in the HIGH position. Resistor 18 is the oscillator plate circuit load, and the voltage developed across it is coupled to detector-converter Tube VT–208 through capacitor 8–2, or to the antenna through capacitors 8–2 and 8–1 in series. Part 16–1 is the screen grid dropping resistor, and part 10–3 is the screen grid bypass capacitor to ground. Capacitor 10–2 bypasses the plate voltage supply.

b. Band Selector Switch. Switch 27 is a double-throw, triple-pole switch with all contacts mounted on ceramic plates. To minimize abnormal capacitive effects, all contacts are made as small as possible and are of the self-aligning, self-wiping type. The switch has a heavy detent which accurately locates the rotor plate in either the LOW or HIGH frequency position.

c. CORRECTOR Control. Capacitor 2, the CORRECTOR control, with a range of 2 micromicrofarads (2$\mu\mu$f), enables the operator to control the variable capacitance of the tuned circuit in order to compensate for slight changes in the circuit. (See par. 94f.)

d. Trimming Capacitors. The trimming capacitors are parts 3–1 and 3–2. These capacitors are adjusted at the factory to build up the fixed capacitance of the LOW and HIGH frequency circuits to the exact values called for by the design of the variable tuning capacitor.

Caution: Do not tamper with these trimmer capacitor settings. To do so will throw the meter completely off calibration.

Parts 4 and 5 are thermal compensator capacitors which prevent frequency drifts due to temperature changes.

e. Oscillator Function. (1) The variable frequency oscillator circuit is in operation at the CHECK and OPERATE positions of the operation switch 28. (See fig. 49.)

(2) At the CHECK position, the output of oscillator Tube VT–193 (7G7) is applied to one of the grids of detector-converter Tube VT–208 (7B8LM) where it is mixed with the output frequency of the crystal circuit. The result is a frequency equal to the difference of the two, and is used to adjust the frequency of the oscillator by means of the CORRECTOR control.

(3) At the OPERATE position, the variable frequency oscillator is in operation, while the crystal oscillator is not. If the antenna is in position, the frequency meter may be used to receive or send any frequency in its range, that is, it may be used as a radio receiver or transmitter.

114. Detector Tube Circuit

It has been stated that the three inner elements of Tube VT–208 (7B8LM) are used in the crystal-oscillator circuit. The remaining elements of this tube (comprising the control grid, screen grid, and plate) are used as a high gain screen grid detector, to which, by tube structure, the crystal oscillator is electronically coupled. (See fig. 48.) Resistor 20–1 is the detector tube grid leak. Resistor 16–2 supplies voltage to the screen grid of Tube VT–208 (7B8LM). Capacitor 10–4 bypasses the screen grid to ground. Capacitor 10–1 is a bypass capacitance across the plate voltage. Note that the antenna plug 29 is connected to ground through the resistor 21. The r-f voltage developed across the load resistor 18 in the plate output circuit of the variable frequency oscillator is coupled to the control grid of this detector through a small fixed capacitor 8–2. The antenna plug 29, mounted on the chassis, is also coupled to the control grid of the detector

880640 O—50——6

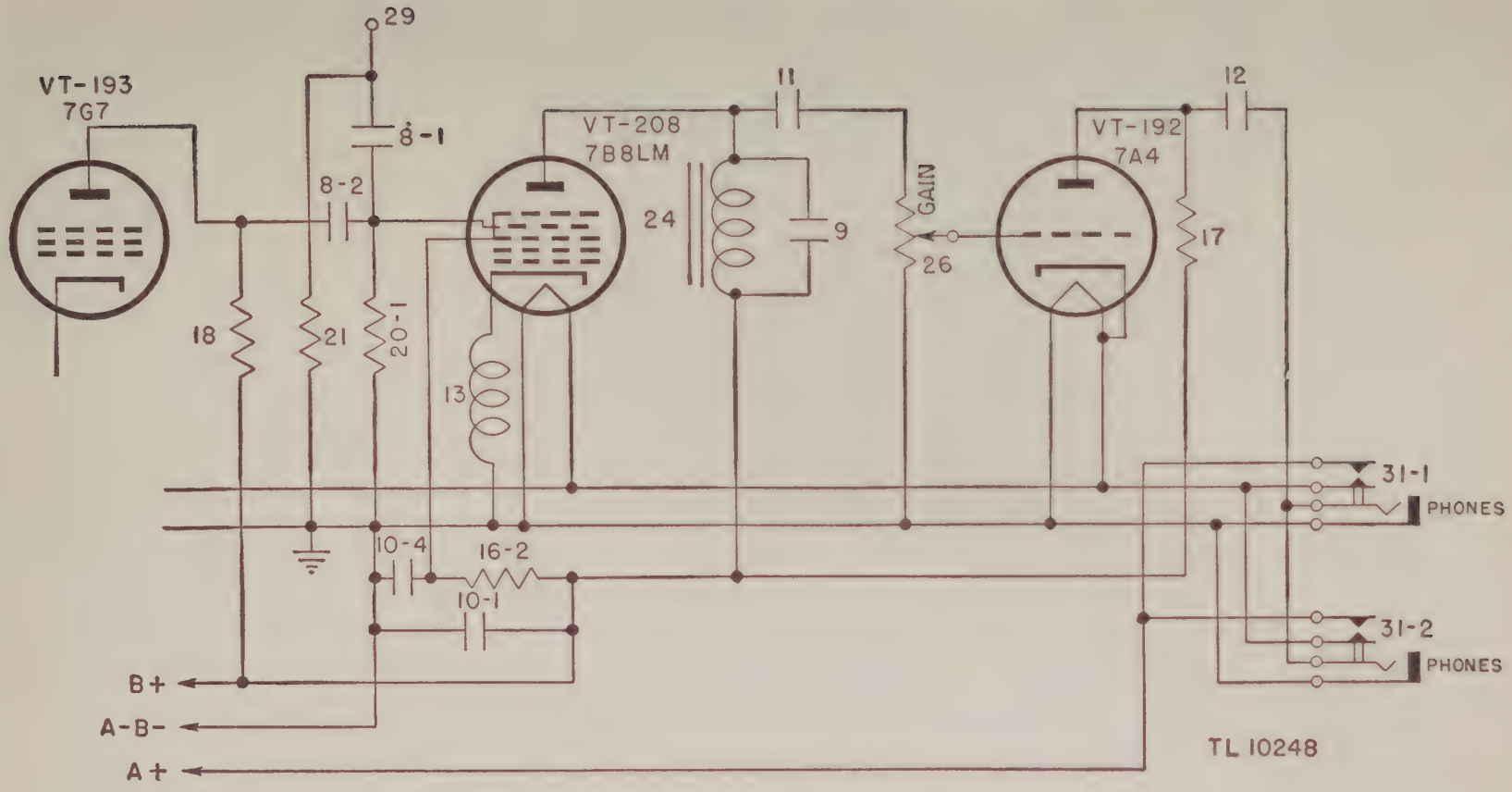


Figure 48. Frequency Meter BC-221-E, functional diagram, detector and audio-amplifier circuits.

through the coupling capacitor 8–1. As a result of these couplings to the control grid, the detector mixes the variable frequency oscillator output with the fundamentals and successive harmonics of the crystal oscillator, when the operation switch 28 is in the CHECK position, and with the radio transmitter frequency to be measured, when the switch is in the OPERATE position. By reference to figures 47 and 48, it can be seen that the antenna plug 29 is also coupled to the variable frequency oscillator output through capacitors 8–1 and 8–2 in series. Thus, the antenna plug 29 serves the dual purpose of a detector input terminal for the measurement of frequencies of external origin and of a variable frequency oscillator output terminal for use in calibrating receivers. When the unit is employed for the latter purpose, a minimum of 2,000 microvolts of radio frequency energy will be available between the antenna terminal and ground (the chassis) at any frequency within the calibrated range.

115. Audio-Amplifying Circuit (par. 25)

The detector plate works into an audio-frequency choke coil 24, which is bypassed by the capacitor 9 to reduce the response to high frequencies. The beat frequency voltages built up across the choke coil are coupled through capacitor 11 and the GAIN control potentiometer 26 to the grid of Tube VT–192 (7A4). The grid of Tube VT–192 returns to ground through the potentiometer 26, and the necessary grid bias voltage is obtained by connecting the cathode to the positive side of the filament. The plate of Tube VT–192 returns to the positive plate supply voltage through the plate load resistor 17. The plate of this tube is coupled also to the PHONES jacks 31–1 and 31–2 through capacitor 12, so that no d-c voltage will be present in the output circuit. The characteristics of the output circuit are such that either high-impedance (15,000 ohms) or low-impedance (2,500 ohms) headsets may be used without any change-over adjustments being necessary.

116. Power Supply Circuit (fig. 49)

All power required for the operation of the meter is introduced through the battery terminal board 36. The common negative filament and negative plate battery leads are connected to the middle terminal which is grounded to the chassis. A fabricated wiring harness is provided for intercell and filament battery to terminal board connections. The operation switch 28 closes both the positive 6-volt supply (A+) and the positive 135-volt supply (B+) as described previously in paragraph 94c. The positive 6-volt supply (A+) is closed to the vacuum tube filaments through the auxiliary switches on the PHONES jacks 31–1 and 31–2, when a headset plug is inserted in one of the jacks. Since the door covering the control panel cannot be closed with the headset plug in place, the *A* and *B* batteries cannot be discharged even though the operation switch is left in an active position when the meter is removed from service.

Section IV. MAINTENANCE

117. General

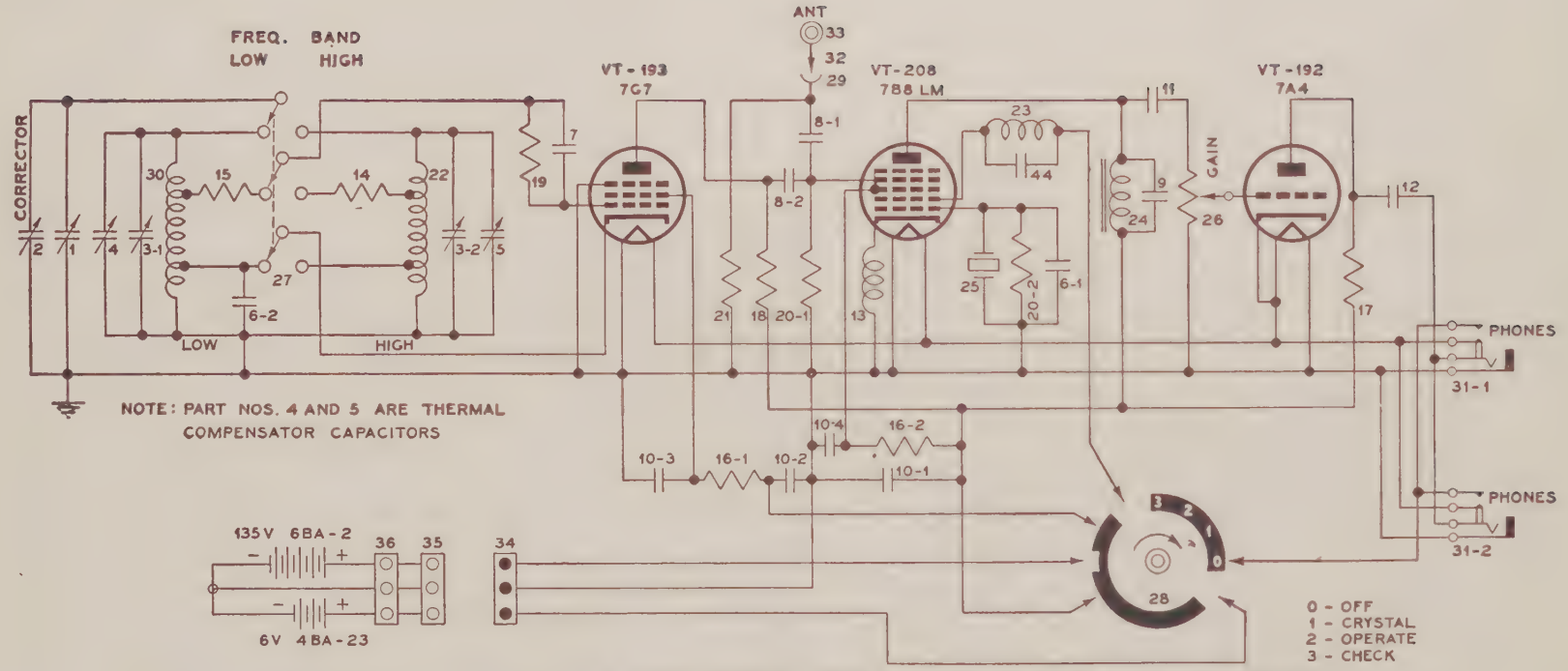
For all details of field maintenance, see paragraphs 26, 27, and 28.

Section V. SUPPLEMENTARY DATA

118. Tabular List of Maintenance Parts for Frequency Meter BC–221–E

NOTE. Order maintenance parts by stock number, name, and description.

Ref. No. symbol	Signal Corps stock No.	Name of part and description	Quan per equip.	Lowest maint. echelon
	2Z481E	BAG: BG–81–E; carrying	1	3d
	2Z551–160	BAG: BG–160–(&)/S; available for amphibious operations	1	Orgn stock
	3A2	BATTERY: BA2; 22.5=v	6	3d
	3A23	BATTERY: BA23; 1.5=v	4	3d
	3E1605–6.5	CORD: CD–605; 6½=ft; 2=cond.; PL–55 at one end; Transformer C–410 at other.	1	3d
	3E1874	CORD: CD–874; 6½=ft; 2=cond.; PL–55 on one end; JB–47 on other end.	1	3d
	2B830(&)	HEADSET: HS–30–(&); component HEADSET: HS–30–(&); repair parts	1	Orgn stock
	2B1300	INSERT: M–300	2	Orgn stock
	2Z9019A	STRAP: ST–19–A	1	3d



REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	200 μμf	9	.004 μf	16-1&2	10,000 OHM	24	300 HENRYS	32	CONTACT SPRING
2	3 to 5 μμf	10-1&2	0.1 μf	17	15,000 OHM	25	CRYSTAL	33	BINDING POST
3-1&2	3 to 29 μμf	10-3&4	0.1 μf	18	50,000 OHM	26	0.5 MEGOHM	34	POWER PLUGS
4	6.5 μμf	11	0.25 μf	19	330,000 OHM	27	SWITCH	35	POWER JACKS
5	5 μμf	12	2 μf	20-1&2	1 MEGOHM	28	SWITCH	36	BATTERY TERM.
6-1&2	25 μμf	13	15.8 MICROHY	21	5,000 OHM	29	ANT PLUG	44	5 μμf
7	15 μμf	14	27 OHM	22	HIGH FREQ. COIL	30	LOW FREQ COIL		
8-1&2	25 μμf	15	1,500 OHM	23	735 MICROHY	31-1&2	JACK		TL 10274

Figure 49. Frequency Meter BC-221-E, schematic diagram.

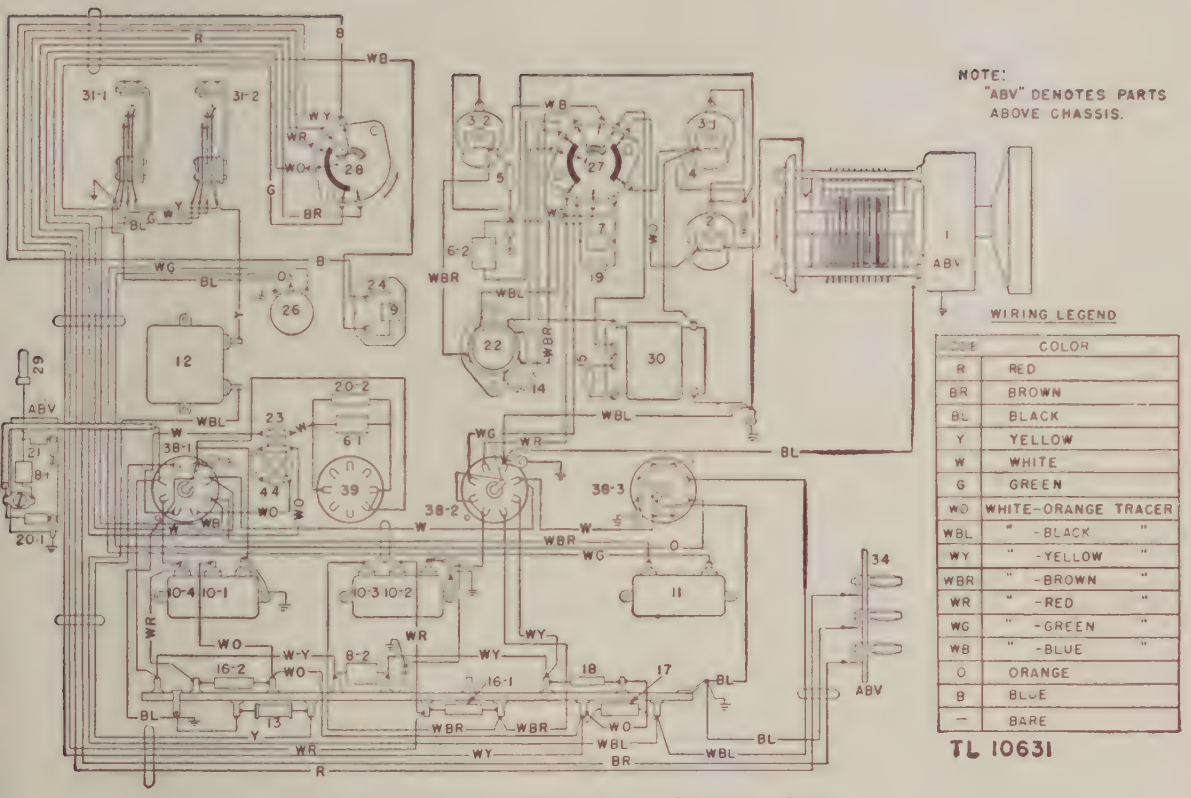


Figure 50. Frequency Meter BC–221–E, chassis wiring diagram.

CHAPTER 5

FREQUENCY METER SETS SCR–211–F, SCR–211–J, SCR–211–K, AND SCR–211–L

Section I. DESCRIPTION

119. General

Frequency Meter Sets SCR–211–F, SCR–211–J, SCR–211–K, and SCR–211–L have been manufactured by the Zenith Radio Corporation on several orders. These four models are similar to the SCR–211–A, SCR–211–C, and SCR–211–D series described in chapter 2. The four models included in this chapter are electrically and mechanically alike, with two exceptions: The values of parts 18, 49, and 50 vary; and parts 49 and 50 were omitted from the early production of the SCR–211–F. Except for the above, the part numbers on the diagrams are the same, with variations in electrical value noted where necessary. For further general information read paragraph 2. The symbol (3) as used in this chapter refers to either the SCR–211–F, SCR–211–J, SCR–211–K, or SCR–211–L.

120. Components

Each Frequency Meter Set SCR–211–(3) includes the following component units:

Quantity	Component
1	Frequency Meter BC–221–(3) includes: 1 Crystal Unit DC–9–(3) (in operating position). 1 Crystal Unit DC–9–(3) (spare, mounted on chassis)[1]. 1 Calibration Book MC–177–(3). 1 Calibration Book MC–177–(3) (spare, untyped, in chassis compartment). 1 Wrench for Bristo No. 8 setscrew (spares compartment).
2	Tube VT–116–B, type 6SJ7Y (one in use, one spare).
2	Commercial tube, type 6A7 (one in use, one spare).
2	Tube VT–76, type 76 (one in use, one spare).
1	Bag BG–81–(3).
1	Instruction book for technical manual for Frequency Meter Set SCR–211–(3).
1	Strap ST–19–A[2].
1	Additional spare set of vacuum tubes (1 each of Tubes VT–116–B, 6A7, and VT–76)[3].

121. Additional Equipment Required

The following equipment, not furnished with the orders, is required to complete each Frequency Meter Set SCR–211–(3):

Quantity	Article
1	Headset P–18 or P–20.
6	Batteries BA–2.
4	Batteries BA–23.
1	Strap ST–19–A*.

* Required for the SCR–211–F only.

122. Total Weight

Frequency Meter Set SCR–211–(3), complete and ready for service, weighs 38 pounds. For typical dimensions, see figure 26.

123. Power Consumption

All power required for the operation of this equipment is supplied by the batteries listed in

1 Not supplied with the BC–221–J, BC–221–K, and BC–221–L.
2 Not supplied with the SCR–211–F.
3 Three additional sets of spare vacuum tubes are supplied with the SCR–211–F. (One set in use, four sets spare, total).

paragraph 121. The current drains at the specified voltage limits are as follows:

Filaments: 5.4 to 6.0 volts, 0.86 to 0.92 ampere.

Plates, etc.: 121.5 to 135.0 volts, 0.0126 to 0.0146 ampere.

These values are typical for operation with the CRYSTAL switch in the OFF position, under which condition maximum plate current is drawn.

124. Controls (par. 2e)

When the snap latch is released and the front cover lowered, the control panel and calibration book are exposed. There are seven operating controls. (see fig. 5.)

a. Two PHONES jacks allow observations by two persons at the same time; for example, student and instructor. A headset must be plugged into one of the jacks before the meter can be set in operation because of the series filament supply switches built into the jacks.

b. The POWER ON-OFF switch breaks both the filament and plate supply voltages and, in connection with the PHONES jacks, controls the operation of the meter.

c. The GAIN control is a volume control used to adjust the input voltage to the audio-amplifier tube and, in turn, the level of sound in the headset.

d. The CRYSTAL OFF-ON switch permits the insertion or removal of the crystal oscillator from the meter circuit. In the OFF position of the switch, the crystal is shorted out; in the ON position, the short around the crystal is removed. The CRYSTAL ON position is used primarily for checking the variable frequency oscillator at CRYSTAL CHECK POINTS, and to furnish whole multiples of 1,000 kc for the calibration of receivers and similar equipment.

e. The FREQ. BAND LOW-HIGH-CRYSTAL ONLY switch permits the selection of the appropriate band of operation of the variable frequency oscillator as indicated by the frequency being checked or calibrated and, in the CRYSTAL ONLY position, prevents operation of the variable frequency oscillator so that the crystal oscillator can be used alone, d above.

f. The frequency of the variable frequency oscillator is controlled by setting the dial labeled DIAL UNITS which is graduated into one hundred divisions. One revolution of the DIAL UNITS dial moves the DIAL HUNDREDS dial one division. (See par. 11.)

g. The CORRECTOR knob controls a small variable capacitor across the variable frequency oscillator tuned circuit, and is used to compensate for small changes in capacity brought about by temperature, humidity, and mechanical changes. It is adjusted at each CRYSTAL CHECK POINT to make the calibration of the instrument as accurate as possible over that part of the scale centered at a given CRYSTAL CHECK POINT and extending halfway to the next higher and next lower CRYSTAL CHECK POINTS.

125. Vacuum Tubes

The vacuum tubes used in the Frequency Meter Set SCR–211–(3) are shown in the following tabulation:

Reference	Function	Signal Corps type nomenclature	Commercial equivalent	Base
VT–116–B*.....	Variable frequency oscillator.	VT–116–B*.....	6SJ7Y*.....	Octal
6A7.....	Crystal oscillator and detector.	None.....	6A7	Small 7 pin
VT–76.....	Audio–frequency amplifier.	VT–76.....	76	Small 5 pin

* Tube VT–116–B is practically the same as Tube VT–116 but has a special electrically low-loss base. In an emergency, a Tube VT–116 can be used in the variable frequency oscillator, but temperature and humidity changes might cause undesirable effects.

Section II.

INSTALLATION AND OPERATION

126. Initial Procedure (par. 7)

If extra spare sets of vacuum tubes, inclosed in a carton, are stored in the battery compartment, remove them when inspecting the equipment and place them in stock.

127. Installation of Batteries (pars. 8 and 38)

128. Antenna (par. 9)

129. Headset (par. 10)

Plug PL–55 or Plug PL–125 of the Headset P–18 or Headset P–20 must be inserted into one of the PHONES jacks before the meter will operate.

130. Preparation for Use

a. To start the meter, insert the headset plug into a PHONES jack and then turn the POWER switch to the ON position. The instrument will operate only when both of these steps have been taken. The meter cannot be left on after the cover is closed since the headset plug must be removed in order to close it.

b. After starting the set by the method described above, allow the vacuum tube filaments to heat for 15 to 20 minutes.

c. In order to test for normal operating conditions, set the FREQ. BAND LOW-HIGH-CRYSTAL ONLY switch to either the LOW or HIGH position and turn the CRYSTAL switch to the ON position. While rotating the DIAL UNITS dial, listen in the headset for tones of increasing and decreasing pitch. These different tones are produced by the changing variable oscillator frequency beating with the various crystal harmonics. The presence of these tones indicates normal operation.

131. Reading the Dial (par. 11)

132. Calibration Book MC–177--(3) (par. 12)

133. Operating Circuits (par. 13)

134. Zero Beat Detection (par. 14)

135. Correction in Calibration

With the POWER and CRYSTAL switches turned to the ON position, and with the FREQ. BAND switch turned to the LOW or HIGH position as required, follow the procedure in paragraph 15. After completion of this procedure, turn the CRYSTAL switch to the OFF position and proceed with any measurements.

136. Crystal Check Points (par. 16)

137. Frequency Measurements

The proper position for the CRYSTAL switch for all measurements, other than the correction of the variable frequency oscillator and the use of the crystal oscillator alone, is OFF. For details on making frequency measurements see paragraph 17.

138. Precautions During Operation (par. 18)

139. Adjustments for Field Upkeep (par. 19)

Section III. FUNCTIONING OF PARTS

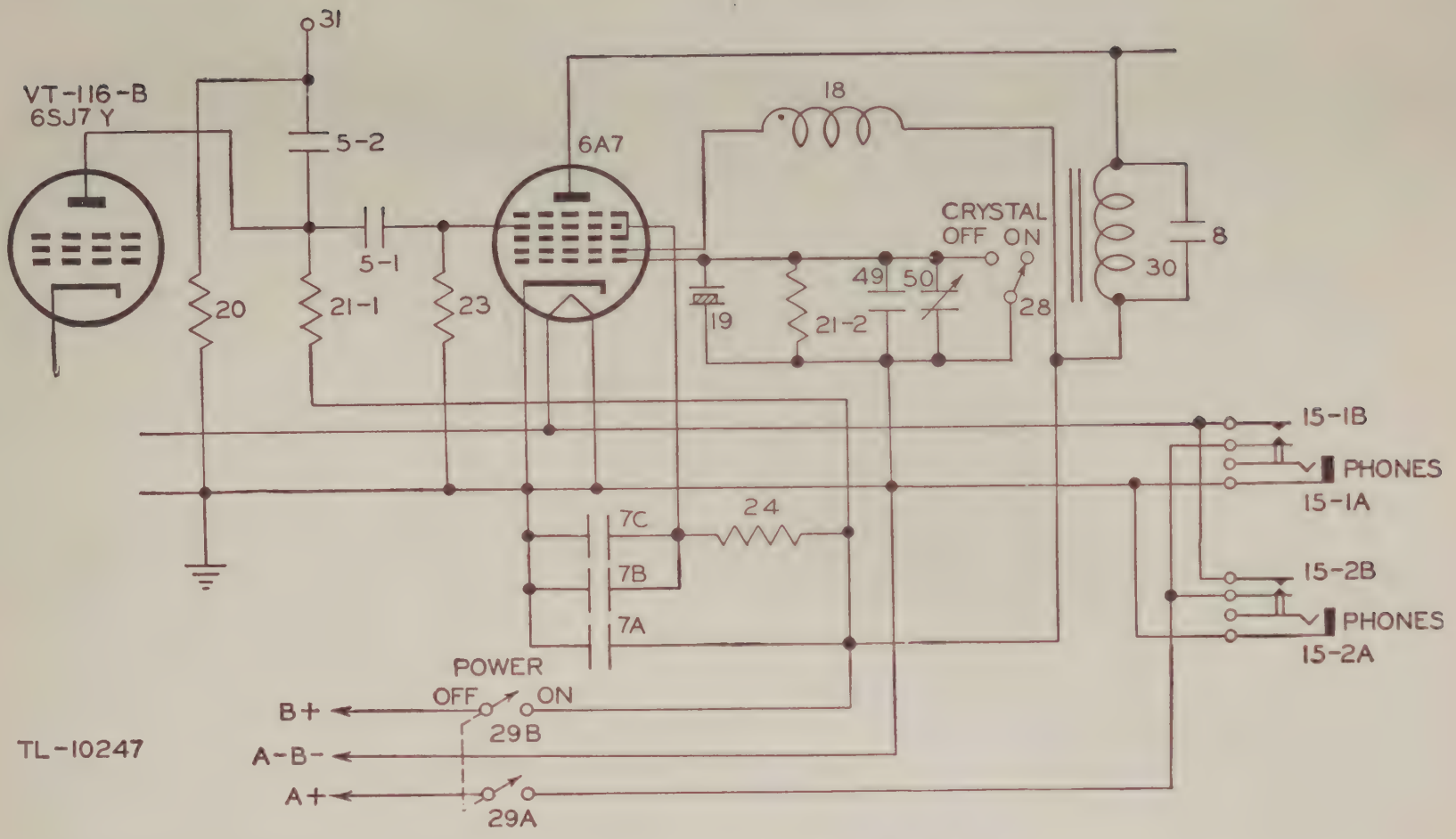
140. General

As stated in paragraph 119, the four models described in this chapter are electrically and mechanically alike, with two exceptions: The values of parts 18, 49, and 50 vary, and parts 49 and 50 were omitted from the early production of the SCR–211–F. One schematic diagram (fig. 54) covers all four models with the above exceptions noted thereon.

141. Circuit Components (par. 21)

142. Crystal Circuit

The cathode, the inner grid, and the anode grid of the type 6A7 tube constitute the active elements of a crystal-controlled triode oscillator (fig. 51) which operates at a fixed frequency of 1,000 kc when the CRYSTAL switch 28 is placed in the ON position. The crystal circuit is removed from operation when the CRYSTAL switch 28 is turned to the OFF position, thus placing a short circuit around the crystal. The circuit is designed to generate considerable harmonic energy so that it can be used to calibrate the variable frequency oscillator at several points over its entire range. The necessary plate circuit impedance is built up across an untuned inductance 18 which is housed in a bakelite case of rugged construction and thoroughly sealed against moisture. Resistor 21–2 is the crystal-oscillator grid leak and furnishes bias for proper oscillator operation. The variable capacitor 50 is connected across the crystal 19 for the purpose of adjusting the frequency of the crystal to a



NOTE: PARTS 49 AND 50 WERE OMITTED IN EARLY MODELS OF THE BC-221-F

Figure 51. Frequency Meter BC-221-(3), functional diagram, crystal-oscillator circuit.

closer point than can be economically obtained by grinding alone. When the frequency meters are adjusted during manufacture, the variable capacitor is set up to produce a frequency of 1,000 kc ± 5 cycles at 20° centigrade. The fixed capacitor 49, shunted across the crystal, minimizes any change in fundamental frequency due to small changes in the crystal capacitance. Note that parts 49 and 50 were omitted from early production of Frequency Meter BC–221–F. Further reference to figure 51 shows that the output of the crystal oscillator is electron coupled to the antenna through the No. 4 grid of the type 6A7 tube and capacitors 5–1 and 5–2 in series. Note that the crystal oscillator can be used alone (par. 22*b* (1) (*b*), by having the CRYSTAL and POWER switches in the ON position and the FREQ. BAND LOW-HIGH-CRYSTAL ONLY switch 27 in the CRYSTAL ONLY position. Resistor 24 supplies voltage to the screen grid of the type 6A7 tube. Capacitors 7b and 7c, in parallel, bypass the screen grid to ground. Capacitor 7a is a bypass capacitance across the plate voltage supply. For further details on the crystal oscillator, see paragraph 22.

143. Variable Frequency Oscillator Circuit (par. 23)

Tube VT–116–B (6SJ7Y) is used in an electron coupled circuit as the variable frequency oscillator. (See fig. 52.)

a. Coils. The two inductors 16 and 17, in the tuned circuits, are wound on ceramic forms and thoroughly sealed against moisture to eliminate the influence of changing atmospheric conditions on the stability of the meter. The active terminals of these coils are connected across the terminals of the main tuning capacitor 1 by means of the band selector (FREQ. BAND LOW-HIGH-CRYSTAL ONLY) switch 27. Each coil and the tuning capacitor, together with other capacitors mentioned below, constitute the resonant circuit that determines the output frequency. The correct operating bias on the control grid of the oscillator tube is provided by the grid-leak resistor 39 between grid and ground. Capacitor 42 couples the grid to taps on the tuned circuits through the band selector switch. The frequency of oscillation is made relatively independent of variations in tube characteristics when the grid connection is tapped down an appreciable distance from the high-potential end of the coil. The resistors 37 and 38, which carry little current, are connected in series with the grid circuit taps on the coils and serve to stabilize the operation of the oscillator circuit by suppressing undesirable oscillations. The second coil tap, located near the grounded end of each coil and connected to the cathode of the oscillator tube through another set of contacts on switch 27, serves to control the amount of feedback in the oscillator circuit. Resistor 21–1 is the oscillator tube plate circuit load. The voltage developed across it is coupled to the detector-converter tube 6A7 through capacitor 5–1 or to the antenna plug 31 through capacitor 5–2. Resistor 22 is the screen grid dropping resistor, and part 44a is the screen grid bypass capacitor to ground. Capacitor 44b bypasses the plate voltage supply. Resistor 20 provides a shunt from the antenna post to ground.

b. Band Selector Switch. Switch 27 is a triple-throw, triple-pole switch with all contacts mounted on ceramic plates. To minimize abnormal capacitive effects, all contacts are made as small as possible and are of the self-aligning, self-wiping type. The switch has a heavy detent which accurately locates the rotor plate in any one of its three positions.

c. CORRECTOR Control. Capacitor 2, the CORRECTOR control with a range of 3 micromicrofarads (3$\mu\mu$f), enables the operator to control the variable capacitance of the tuned circuit in order to compensate for slight changes in the circuit. (See par. 124g.)

d. Trimming Capacitors. The trimming capacitors are parts 3 and 4. These are equipped with thermal compensator capacitors, parts 6 and 43 which prevent frequency drifts due to temperature changes. These trimming capacitors are adjusted at the factory to build up the fixed capacitance of the LOW and HIGH frequency circuits to the exact values called for by the design of the variable tuning capacitor.

Caution: Do not tamper with these trimmer capacitor settings. To do so will throw the meter completely off calibration.

e. Oscillator Function. (1) The variable frequency oscillator is in operation whenever the POWER switch 29 is in the ON position, the FREQ. BAND switch 27 is in either the LOW or HIGH position, and a headset is plugged into a PHONES jack. (See fig. 54.)

(2) At the CRYSTAL ON position of the CRYSTAL switch 28, and with the FREQ. BAND switch 27 in the LOW or HIGH position, the output of oscillator Tube VT–116–B is applied to one of the grids of detector-con-

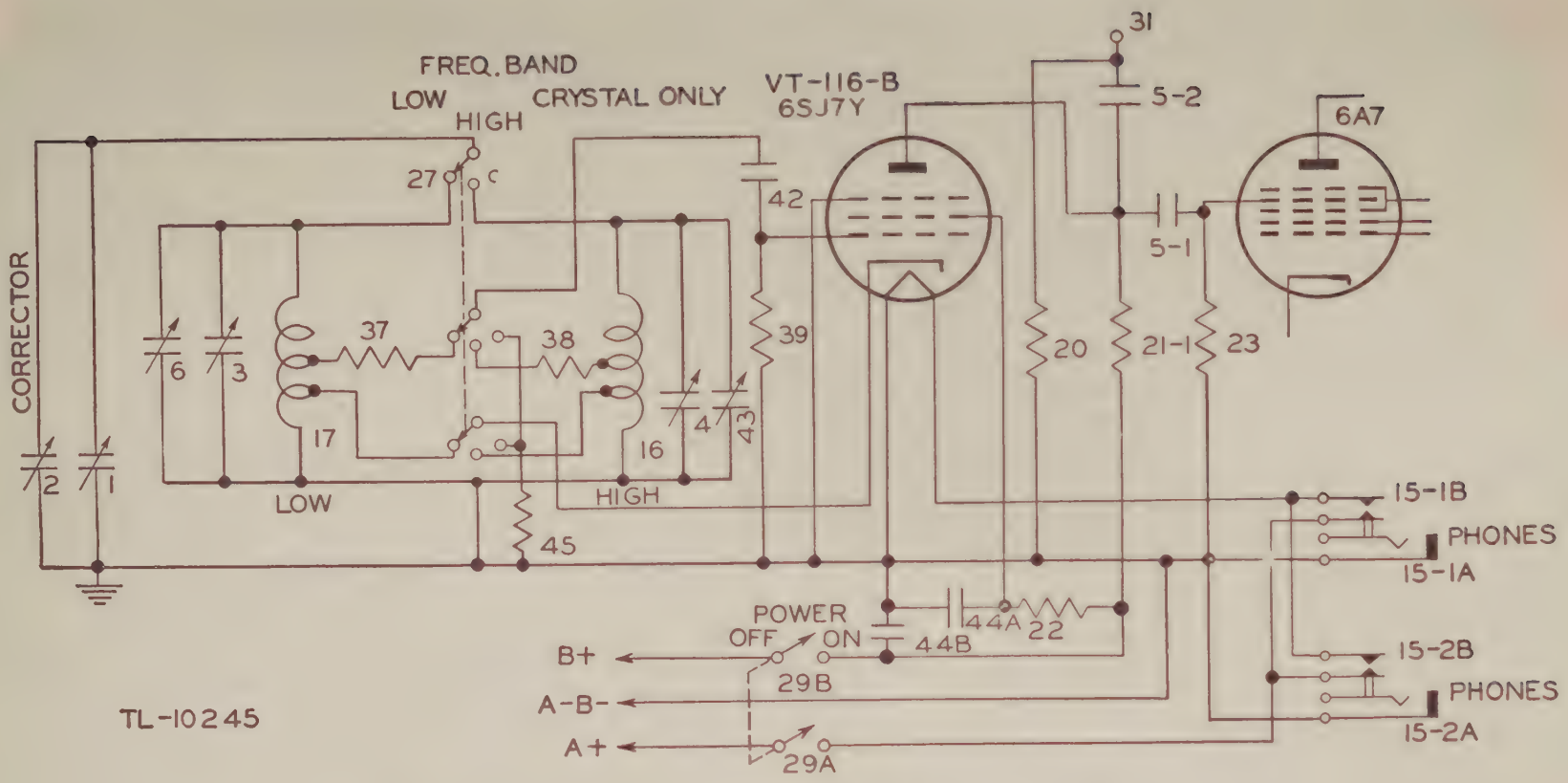


Figure 52. Frequency Meter BC-221-(3), functional diagram, variable frequency oscillator circuit.

verter tube 6A7 where it is mixed with the output frequency of the crystal circuit. The result is a frequency equal to the difference of the two and is used to adjust the frequency of the oscillator with the CORRECTOR control.

(3) With the switches set the same as in (2) above, except that the CRYSTAL switch 28 is in the OFF position, the variable frequency oscillator is in operation while the crystal oscillator is not. If the antenna is in position, the frequency meter may be used to receive or send any frequency in its range; that is, it may be used as a radio receiver or transmitter.

(4) At the CRYSTAL ON position of the CRYSTAL switch 28, and with the FREQ. BAND switch 27 in the CRYSTAL ONLY position the grid and cathode of the variable frequency oscillator tube are connected to ground through resistor 45. This prevents the variable frequency oscillator from operating and permits the crystal oscillator to be used alone. (See par. 22b (1) (*b*).)

144. Detector Tube Circuit

It has been stated that the three inner elements of the type 6A7 tube are used in the crystal oscillator circuit. The remaining elements of the tube (comprising the control grid, screen grid, and plate) are used as a high gain screen grid detector to which, by tube structure, the crystal oscillator is electronically coupled. (See fig. 53.) The r-f voltage, developed across the load resistor 21–1 in the plate output circuit of the variable frequency oscillator is coupled to the control grid of this detector through a small fixed capacitor 5–1. The antenna plug 31, mounted on the chassis, is also coupled to the control grid of the detector through the coupling capacitors 5–2 and 5–1 in series. Resistor 23 is the detector tube grid leak. As a result of these couplings to the control grid, and dependent on the position of the CRYSTAL and FREQ. BAND switches, the detector mixes the variable frequency oscillator output with the fundamental and successive harmonics of the crystal oscillator or with the radio transmitter frequency to be measured. When the crystal switch is thrown to the OFF position, the crystal 19 and its associated circuit elements are short-circuited and the inner grid of the type 6A7 tube is grounded. (See fig. 51.) By reference to figures 52 and 53, it can be seen that the antenna plug 31 is also coupled directly to the variable frequency oscillator output through capacitor 5–2 alone. Thus, the antenna plug 31 serves the dual purpose of a detector input terminal for the measurement of frequencies of external origin and of a variable frequency oscillator output terminal for use in calibrating receivers. When the unit is employed for the latter purpose, a minimum of 2,000 microvolts of radio-frequency energy will be available between the antenna terminal and the ground (the chassis) at any frequency within the calibrated range.

145. Audio-Amplifying Circuit (par. 25)

The detector plate works into an audio-frequency choke coil 30, which is bypassed by the capacitor 8 to reduce the response to high frequencies. The beat frequency voltages built up across the choke coil are coupled through capacitor 9 and the GAIN control potentiometer 26 to the grid of Tube VT–76 (76). The grid of Tube VT–76 returns to ground through the potentiometer 26 the desired bias voltage being obtained by connecting the cathode to the positive side of the filament. The plate of Tube VT–76 returns to the positive plate-supply voltage through the load resistor 25, the latter being bypassed to ground through capacitor 10–2. The plate of Tube VT–76 is also coupled to the PHONES jacks 15–1a and 15–2a through capacitor 10–3 so that no d-c voltage will be present in the output circuit. The characteristics of the output circuit are such that either high-impedance (15,000 ohms) or low-impedance (2,500 ohms) headsets may be used without any change-over adjustments being necessary.

146. Power Supply Circuit (fig. 54)

All power required for the operation of the meter is introduced through the battery terminal board 36. The common negative filament and negative plate battery leads are connected to the middle terminal which is grounded to the chassis. A fabricated wiring harness is provided for intercell and filament battery to terminal board connection. When a headset plug is inserted into one of the jacks, section 29a of the POWER switch closes the positive 6-volt supply terminal (A+) to the vacuum-tube filaments through the auxiliary switches 15–1b and 15–2b on the PHONES jacks 15–1a and 15–2a, and section 29b connects the positive 135-volt terminal (B+) to all plate and screen circuits. Since the door covering the control panel cannot be closed with the headset plug in place the *A* and *B* batteries cannot be discharged even though the POWER switch is left in the ON position when the meter is removed from service.

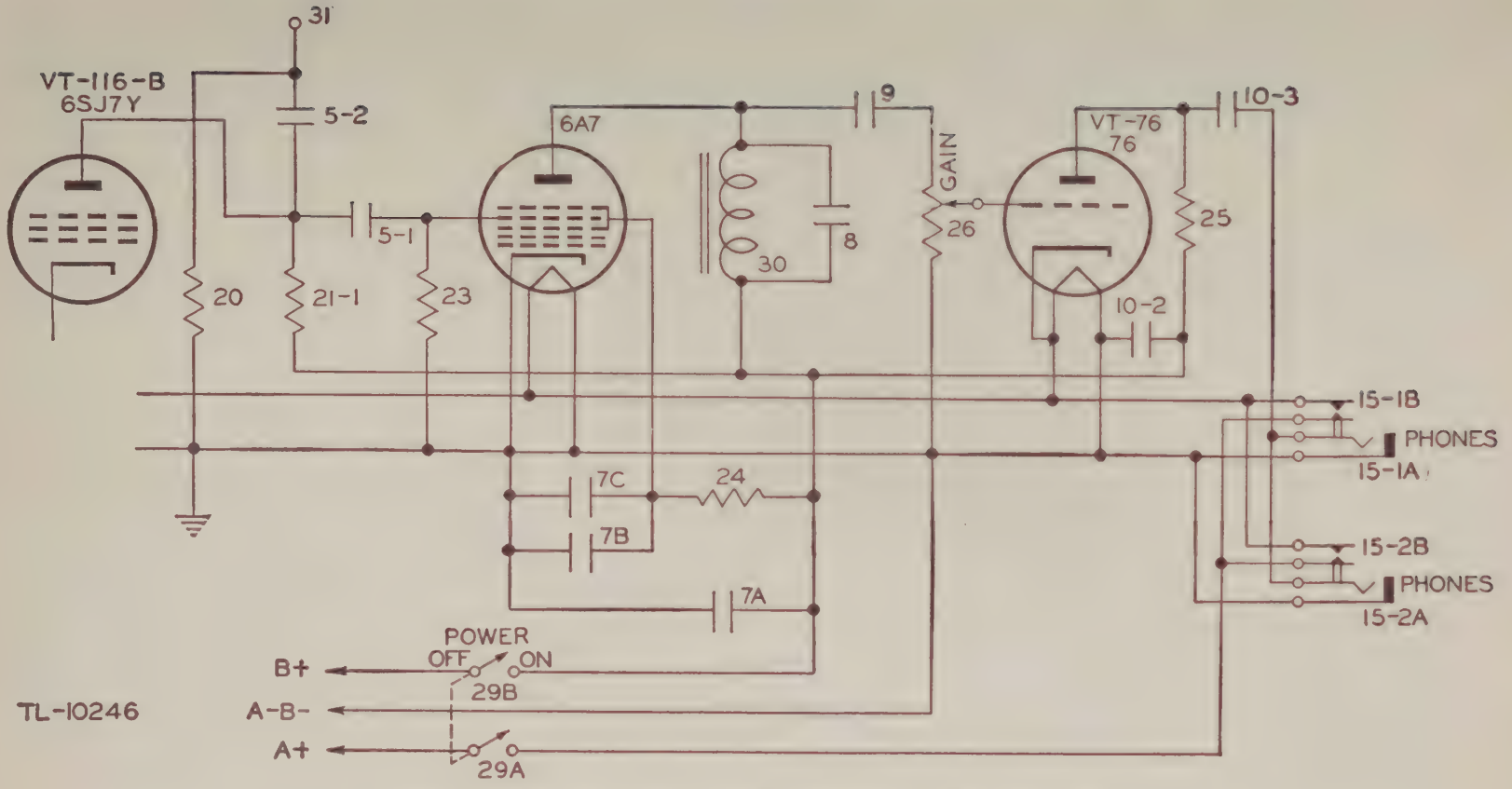


Figure 53. Frequency Meter BC-221-(3), functional diagram, detector and audio-amplifier circuits.

Section IV. MAINTENANCE

147. General

For all details of field maintenance, see paragraphs 26, 27, and 28.

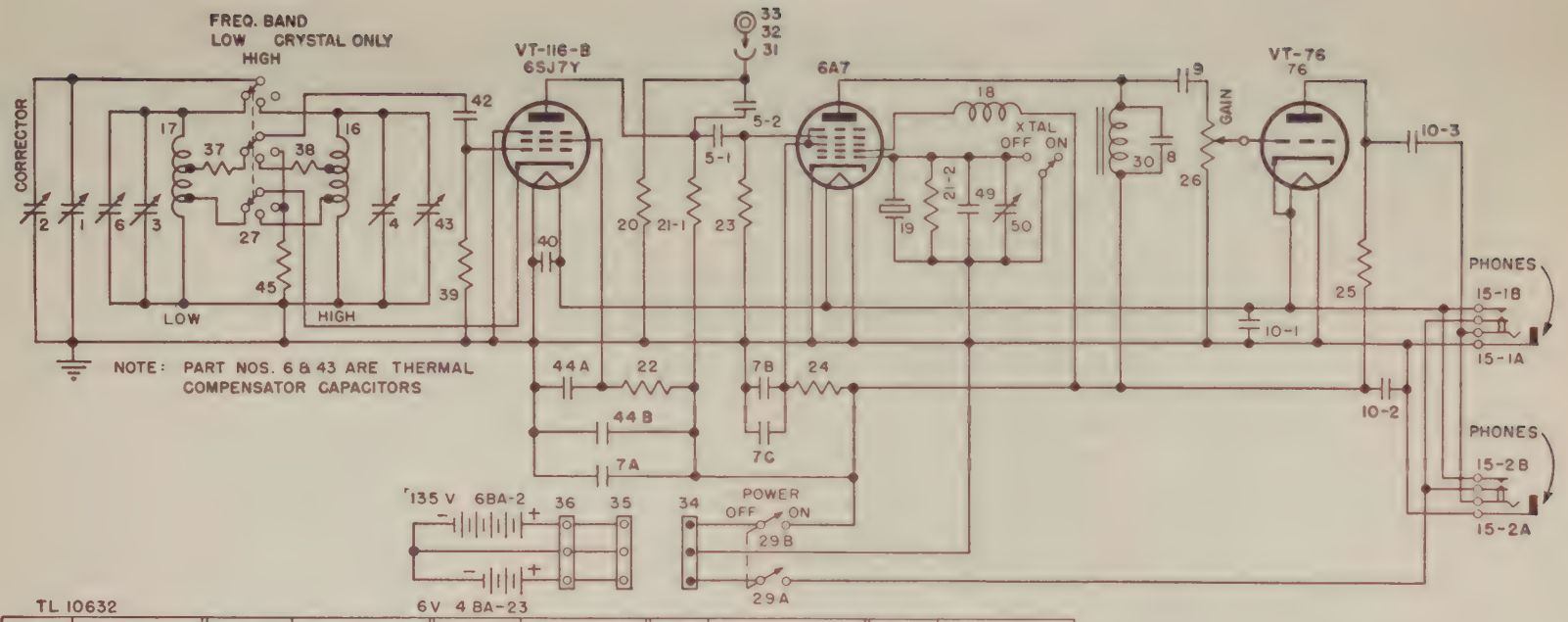
Section V. SUPPLEMENTARY DATA

148. Tabular List of Maintenance Parts for Frequency Meters BC–221–F, BC–221–J, BC–221—K, and BC–221–L

NOTE. Order maintenance parts by stock number, name, and description.

Ref. No. symbol	Signal Corps stock No.	Name of part and description	Quan. per equip.	Lowest maint. echelon
	2Z481F 2Z481J 2Z481K 2Z481L	BAG: BG–81–F; carrying BAG: BG–81–J; carrying BAG: BG–81–K; carrying BAG: BG–81–L; carrying	1* 1* 1* 1*	3d
	2Z551–160	BAG: BG–160–(&)/S; available for amphibious operations	1	Orgn stock
	3A2	BATTERY: BA2; 22.5=v	6	3d
	3A23	BATTERY: BA23; 1.5=v	4	3d
	3E1605–6.5	CORD: CD–605; 6½=ft; 2=cond.; PL–55 at one end; Transformer C–410 at other	1	3d
	3E1874	CORD: CD–874; 6½=ft; 2=cond.; PL–55 on one end; JB–47 on other end	1	3d
	2B830(&)	HEADSET: HS–30–(&); component HEADSET: HS–30–(&); repair parts	1	Orgn stock
	2B1300	INSERT: M–300	2	Orgn stock
	2Z9019A	STRAP: ST–19–A	1	3d

* Only one Bag BG–81–F, BG–81–J, BG–81–K, or BG–81–L is furnished per equipment.



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REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	160 μμf	10-1.2&3	0.5 μf	20	5,000 OHM	29	SWITCH	38	350 OHM
2	3 μμf	15-1A	JACK	21-1&2	50,000 OHM	30	450 HENRYS	39	150,000 OHM
3	10 μμf	15-1B	FIL. SWITCH	22	8,750 OHM	31	ANT. PLUG	40	.001 μf
4	10 μμf	15-2A	JACK	23	1 MEGOHM	32	CONTACT SPRING	42	100 μμf
5-1&2	10 μμf	15-2B	FIL. SWITCH	24	30,000 OHM	33	BINDING POST	43	10 μμf
6	7 uuf	16	34.0 MICROHY	25	15,000 OHM	34	POWER PLUGS	44A&B	0.1 μf
7A,B,C	0.1 μf	17	9.05 MILLIHY	26	0.5 MEGOHM	35	POWER JACKS	45	10 000 OHM
8	.001 μf	18	R.F. CHOKE	27	SWITCH	36	BATTERY TERM	49	13 μμf*
9	.02 μf	19	CRYSTAL	28	SWITCH	37	4,500 OHM	50	11 μμf*

* NOTE: PART NOS. 49 AND 50 WERE OMITTED FROM EARLY MODELS OF THE BC-221-F. ALSO PART NOS. 49 & 50 ARE 5 μμf AND 14.5 μμf, RESPECTIVELY IN THE BC-221-J.

Figure 54. Frequency Meter BC-221-(3), schematic diagram.

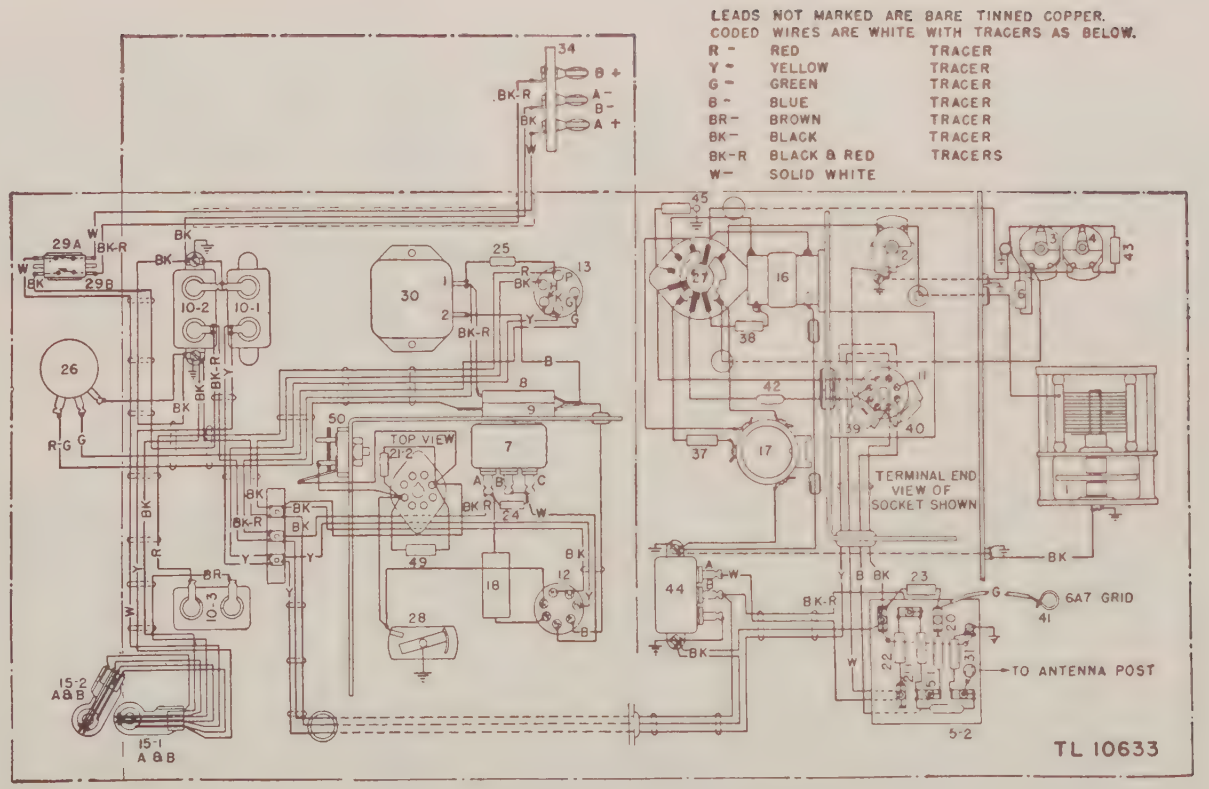

LEADS NOT MARKED ARE BARE TINNED COPPER.
CODED WIRES ARE WHITE WITH TRACERS AS BELOW.
R - RED TRACER
Y - YELLOW TRACER
G - GREEN TRACER
B - BLUE TRACER
BR - BROWN TRACER
BK - BLACK TRACER
BK-R BLACK & RED TRACERS
W - SOLID WHITE
TOP VIEW
TERMINAL END VIEW OF SOCKET SHOWN
6A7 GRID
TO ANTENNA POST
TL 10633

Figure 55. Frequency Meter BC–221–(3), chassis wiring diagram.

CHAPTER 6

FREQUENCY METER SETS SCR–211–M, SCR–211–O, SCR–211–R, AND SCR–211–AC

Section I. Description

149. General

Frequency Meter Set SCR–211–M has been manufactured by the Bendix Radio Corporation on several orders. Frequency Meter Sets SCR–211–O, SCR–211–R, and SCR–211–AC have been manufactured by the Rauland Corporation. Sets SCR–211–O and SCR–211–R are exactly alike in all electrical and mechanical details, except for the difference in nomenclature and order numbers. The SCR-211-M and the SCR–211–AC are very similar to these two models and to each other, but have variations in the arrangements of the variable frequency oscillator circuit and minor differences in part sizes and designations. These differences are discussed in detail in applicable parts of this chapter. For further general information see paragraph 2. The symbol (4) as used in this chapter refers to either the SCR–211–M, SCR–211–O, SCR–211–R, or SCR–211–AC.

150. Components

Each Frequency Meter Set SCR–211–(4) includes the following component units:

Quantity	Component
1	Frequency Meter BC–221–(4) includes: 1 Crystal Unit DC–9 M, DC–9–P, or DC–9 AD (in operating position)[1]. 1 Calibration Book MC–177–(4). 1 Wrench for Bristo No. 6 setscrew (spares compartment)[2]. 1 Wrench for Bristo No. 8 setscrew (spares compartment).
2	Tube VT–116–B, type 6SJ7Y (one in use, one spare).
2	Tube VT–167, type 6K8 (one in use, one spare).
2	Tube VT–116, type 6SJ7 (one in use, one spare).
1	Bag BG–81–(4)[3].
1	Strap ST–19–A.
1	Instruction book or technical manual for Frequency Meter Set SCR–211–(4).
1	Additional spare set of vacuum tubes (1 each of Tubes VT–116–B, VT–116, and VT–167)[4]

[1] Any crystal unit with nomenclature N or higher can be used interchangeably with any frequency meter set with nomenclature N or higher.
[2] Included with BC–221–M only.
[3] Bag BG–81 D is issued with the SCR–211–M. The SCR–211–AC comes in a wooden cabinet and the cover Bag BG–81–AC is not considered as a component part.
[4] Supplied only with Order No. 17134–Phila–42 on the SCR–211–M.

151. Additional Equipment Required

The following equipment, not furnished with the orders, is required to complete each Frequency Meter Set SCR–211–(4):

Quantity	Article
1	Headset P–18 or P–20[1].
1	Headset HS–30–(&)[2].
1	Cord CD–605[2].
6	Batteries BA–2.
4	Batteries BA–23.

[1] Normally used with the SCR–211–M, SCR–211–O, and SCR–211–R, but can be used with the SCR–211–AC if Headset HS–30–(&) and Cord CD–605 are not available.
[2] Normally used with the SCR–211–AC, but sometimes issued for use with the SCR–211–O and SCR–211–R.

152. Total Weight

Frequency Meter Set SCR–211–(4), complete and ready for service, weighs as follows: SCR–211–M, SCR–211–O, and SCR–211–R, approximately 38 pounds; SCR–211–AC, approximately 43 pounds. For typical dimensions, see figures 26 and 27.

153. Power Consumption

All power required for the operation of this equipment is supplied by the batteries listed in paragraph 151. The following are the current drains at the specified voltage limits:

a. For the SCR–211–M, SCR–211–O, and SCR–211–R:

Filaments: 5.4 to 6.0 volts, 0.8 to 0.9 ampere.

Plates, etc.: 121.5 to 135.0 volts, 0.012 to 0.014 ampere.

b. For the SCR–211–AC:

Filaments: 5.4 to 6.0 volts, 0.86 to 0.91 ampere.

Plates, etc.: 121.5 to 135.0 volts, 0.015 to 0.017 ampere.

c. These values are typical for operation with the operation switch in the XTAL CHECK position, under which condition maximum plate current is drawn.

154. Controls (par. 2e)

When the snap latch is released and the front cover lowered, the control panel and calibration book are exposed. There are seven operating controls. (See fig. 6.)

a. Two PHONES jacks allow observations by two persons at the same time; for example, student and instructor. A headset must be plugged into one of the jacks before the meter can be set in operation because of the series filament supply switches built into the jacks.

b. The POWER ON-OFF switch breaks both the filament and plate supply voltages and in connection with the PHONES jacks, controls the operation of the meter.

c. The GAIN control is a volume control used to adjust the input voltage to the audio-amplifier tube, and in turn the level of sound in the headset.

d. The HET. OSC.-XTAL CHECK-XTAL ONLY control is the operation switch of the BC–221–(4). In the HET. OSC. position, plate voltage is removed from the crystal oscillator circuit and all of the remaining circuits remain in operation. In the XTAL CHECK position, plate voltage is supplied to all circuits and the entire meter is in operation. In the XTAL ONLY position, plate voltage is removed from the variable frequency oscillator, while all of the remaining circuits are in operation. The XTAL CHECK position places maximum load on the batteries. Further details of this switch are described in section III of this chapter since there is some variation among the models described.

e. The FREQ. BAND LOW-HIGH switch permits the selection of the appropriate band of operation of the variable frequency oscillator as indicated by the frequency being checked or calibrated.

f. The frequency of the variable frequency oscillator is controlled by the setting of the dial labeled "Dial Units" which is graduated into one hundred dial divisions. One revolution of the DIAL UNITS dial moves the DIAL HUNDREDS dial one division. (See par. 11.)

g. The CORRECTOR knob controls a small variable capacitor across the variable frequency oscillator tuned circuit, and is used to compensate for small changes in capacity brought about by temperature humidity, and mechanical changes. It is adjusted at each CRYSTAL CHECK POINT to make the calibration of the instrument as accurate as possible over that part of the scale centered at a given CRYSTAL CHECK POINT and extending halfway to the next higher and next lower CRYSTAL CHECK POINTS.

155. Vacuum Tubes

The vacuum tubes used in the Frequency Meter Set SCR–211–(4) are shown in the following tabulation:

Reference	Function	Signal Corps type nomenclature	Commercial equivalent	Base
VT–116–B*..	Variable frequency oscillator.	VT–116–B*.....	6SJ7Y*...	Octal
VT–167.....	Crystal oscillator and detector.	VT–167.....	6K8.....	Octal
VT–116.....	Audio-frequency amplifier	VT–116.....	6SJ7.....	Octal

* Tube VT-116-B is practically the same as Tube VT–116 but has a special electrically low-loss base. In an emergency, a Tube VT–16 can be used in the variable frequency oscillator, but temperature and humidity changes might cause undesirable effects.

Section II.
INSTALLATION AND OPERATION

156. Initial Procedure (par. 7)

Make sure a spare set of vacuum tubes is installed in the space provided. If an extra spare set of vacuum tubes, inclosed in a carton, is stored in the battery compartment, remove it when inspecting the equipment and place it in stock.

157. Installation of Batteries

For the SCR–211–M, SCR–211–O, and SCR–211–R see paragraphs 8 and 38. For the SCR–211–AC see paragraphs 8 and 187b.

158. Antenna (par. 9)

159. Headset (par. 10)

A headset plug must be inserted into one of the PHONES jacks before the meter will operate.

160. Preparation for Use

a. To start the meter, insert the headset plug into a PHONES jack and then turn the POWER switch to the ON position. The instrument will operate only when both of these steps have been taken.

b. After starting the set by the method described above allow the vacuum tube filaments to heat for 15 to 20 minutes.

c. In order to test for normal operating conditions, set the operation switch to the XTAL CHECK position. While rotating the DIAL UNITS dial, listen in the headset for tones of increasing and decreasing pitch. These different tones are produced by the changing variable oscillator frequency beating with the various crystal harmonics. The presence of these tones indicates normal operation.

161. Reading the Dial (par. 11)

162. Calibration Book MC–177–(4) (par. 12)

163. Operating Circuits (par. 13)

164. Zero Beat Detection (par. 14)

165. Correction in Calibration

With the POWER switch in the ON position, the FREQ. BAND switch turned to the LOW or HIGH position as required, and the operation switch turned to the XTAL CHECK position, follow the procedure in paragraph 15. After completing this procedure, turn the operation switch to the HET. OSC. position and proceed with any measurements.

166. Crystal Check Points (par. 16)

167. Frequency Measurements (par. 17)

The proper position of the operation switch of the BC–221–(4) is HET. OSC. for making frequency measurements as described in paragraph 17.

168. Precautions During Operation (par. 18)

169. Adjustments for Field Upkeep (par. 19)

Section III. FUNCTIONING OF PARTS

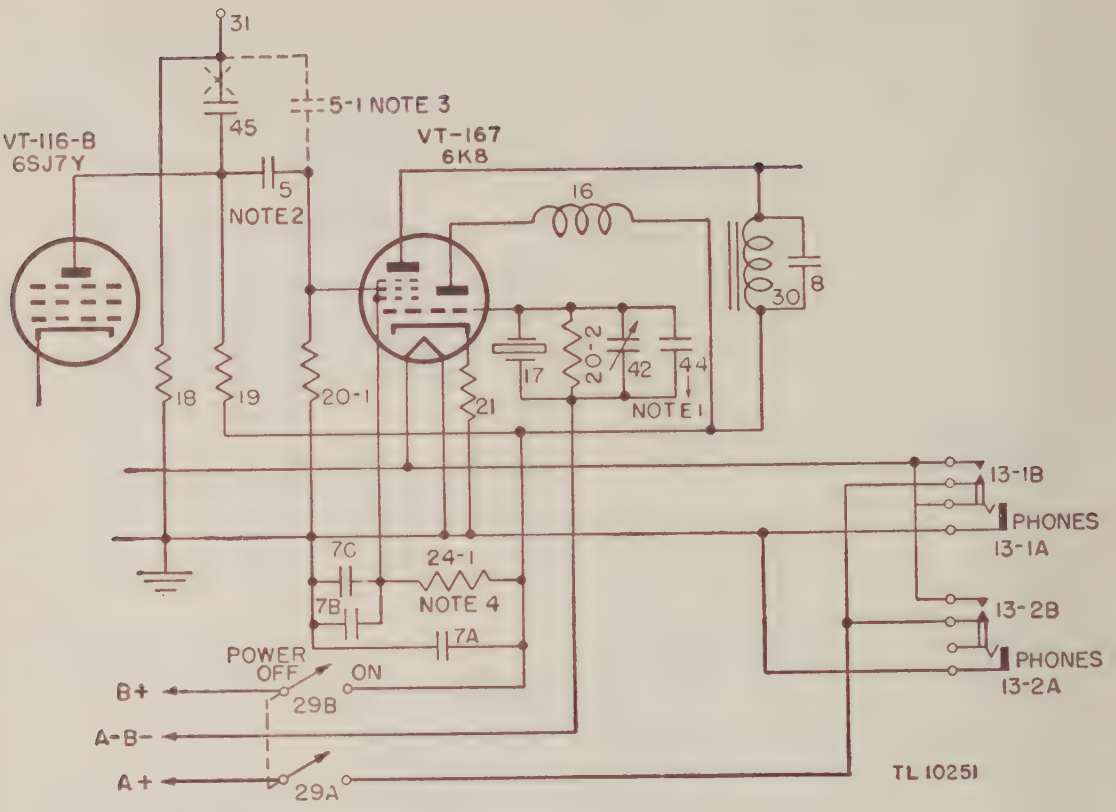
170. General

Frequency Meter BC–221–(4) is very similar to the BC–221–B, BC–221–Q, and BC–221–E (described in preceding chapters of this manual) as far as circuit operation is concerned. The BC–221–O and BC–221–R are exactly alike and are treated as such in this section. The BC–221–M and the BC–221–AC are very similar to these two models and to each other, but vary in the variable frequency oscillator circuits as well as in part sizes and designations. These variations are covered by separate diagrams of the operating circuits, and such additional explanatory remarks as may be required.

171. Circuit Components (par. 21)

172. Crystal Circuit

The crystal circuit uses the triode section of Tube VT–167 (6K8) shown in figure 56. The oscillator operates at the fixed frequency of 1,000 kc when the operation switch 28 is placed in the XTAL CHECK or XTAL ONLY position. The operation switch controls the crystal oscillator by opening or closing its plate voltage circuit. The oscillator circuit is designed to generate considerable harmonic energy so that it can be used to calibrate the variable frequency oscillator at several points over its entire range as well as to supply whole multiples of 1,000 kc



NOTE 1: PART NO. 44-2 IN THE BC-221-AC.
NOTE 2: PART NO. 5-2 IN THE BC-221-AC.
NOTE 3: CONNECTION SHOWN DASHED AND OPEN CIRCUIT SHOWN —✕— APPLIES TO BC-221-AC ONLY.
NOTE 4: PART NOS. 7B AND 7C ARE REPLACED BY PART NO. 43-2B, AND PART NO 7A IS OMITTED IN THE BC-221-AC.

Figure 56. Frequency Meter BC–221–(4), functional diagram, crystal-oscillator circuit.

for the calibration of receivers and similar equipment. The necessary plate circuit impedance is built up across an untuned inductance 16, which is thoroughly sealed against moisture. The variable capacitor 42 is connected across the crystal 17 for the purpose of adjusting the frequency of the crystal to a closer point than can be economically obtained by grinding alone. When the frequency meters are adjusted during manufacture, the variable capacitor is set up to produce a frequency of 1,000 kc ± 5 cycles at 20° centigrade. The fixed capacitor 44 (part No. 44–2 in the BC–211–AC), shunted across the crystal, minimizes any change in fundamental frequency due to small changes in the crystal capacitance. Resistor 20–2 is the oscillator grid leak and works in conjunction with the tube cathode resistor 21 to furnish bias for proper oscillator operation. Further reference to figure 56 shows that the output of the crystal oscillator is electron coupled to the antenna through the No. 3 grid of the hexode section of Tube VT–167 and capacitors 5 and 45 in series (through capacitor 5–1 only in the BC–221–AC). For further details on the crystal oscillator, see paragraph 22.

173. Variable Frequency Oscillator Circuit (par. 23)

Tube VT–116–B (6SJ7Y) is used in an electron coupled circuit as the variable frequency oscillator. (See figs. 57, 58, and 59.)

a. Coils. The two inductors 14 and 15, in the tuned circuits, are wound upon ceramic forms and coated with a special wax to eliminate the influence of changing atmospheric conditions on the stability of the meter. The active terminals of these coils are connected across the terminals of the main tuning capacitor 1 by means of the band selector (FREQ. BAND LOW-HIGH)

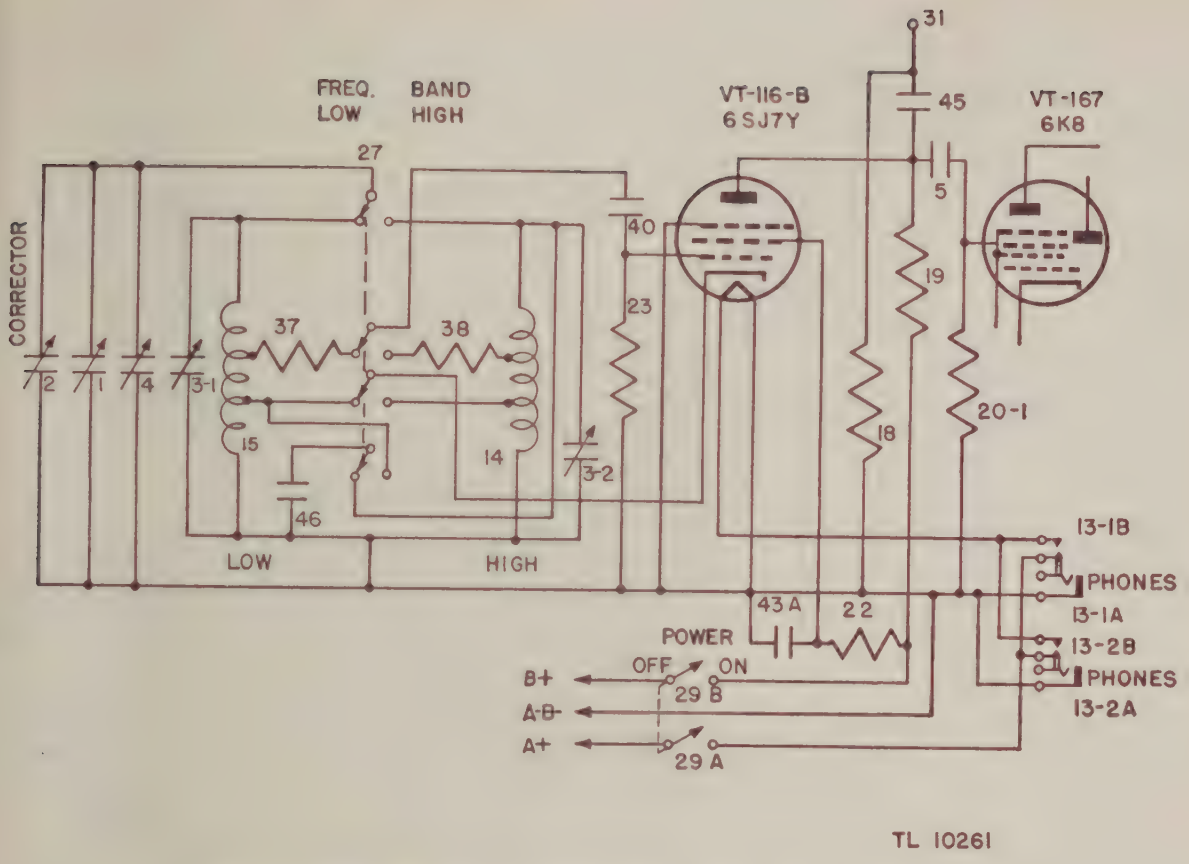


Figure 57. Frequency Meter BC–221–M, functional diagram, variable frequency oscillator circuit.

switch 27. Each coil and the tuning capacitor, together with other capacitors mentioned below, constitute the resonant circuit that determines the output frequency. The correct operating bias on the control grid of the oscillator tube is provided by the grid-leak resistor 23. Note the different connections of the grid-leak resistor employed. In the BC–221–M, BC–221–O, and BC–221–R the grid leak is connected between grid and ground, and capacitor 40 couples the grid to the tuned circuit through the band selector switch. In the BC–221–AC the grid leak, in parallel with the capacitor 40, is connected in the coupling lead from the grid to the tuned circuit. The operation of both methods of connection is the same. The frequency of oscillation is made relatively independent of variations in tube characteristics when the grid connection is tapped down an appreciable distance from the high-potential end of the coil. The resistors 37 and 38, which carry little current, are connected in series with the grid circuit taps on the coils and serve to stabilize the operation of the oscillator circuit by suppressing undesirable oscillations. The second coil tap, located near the grounded end of each coil and connected to the cathode of the oscillator tube through another set of contacts on switch 27, serves to control the amount of feed-back in the oscillator circuit. In the BC–221–AC only, resistor 46 in this lead to the LOW frequency coil gives additional cathode bias voltage when the band selector switch is in the LOW position. Resistor 19 is the oscillator tube plate circuit load, and the voltage developed across it is coupled to detector-converter Tube VT–167 through capacitor 5 (capacitor 5–2 in the BC–221–AC), or to the antenna through capacitor 45 (capacitors 5–2 and 5–1 in series in the BC–221–AC). Resistor 22 is the screen grid dropping resistor, and part 43a (capacitor 43–1a in the BC–221–AC) is the screen grid bypass capacitor to ground.

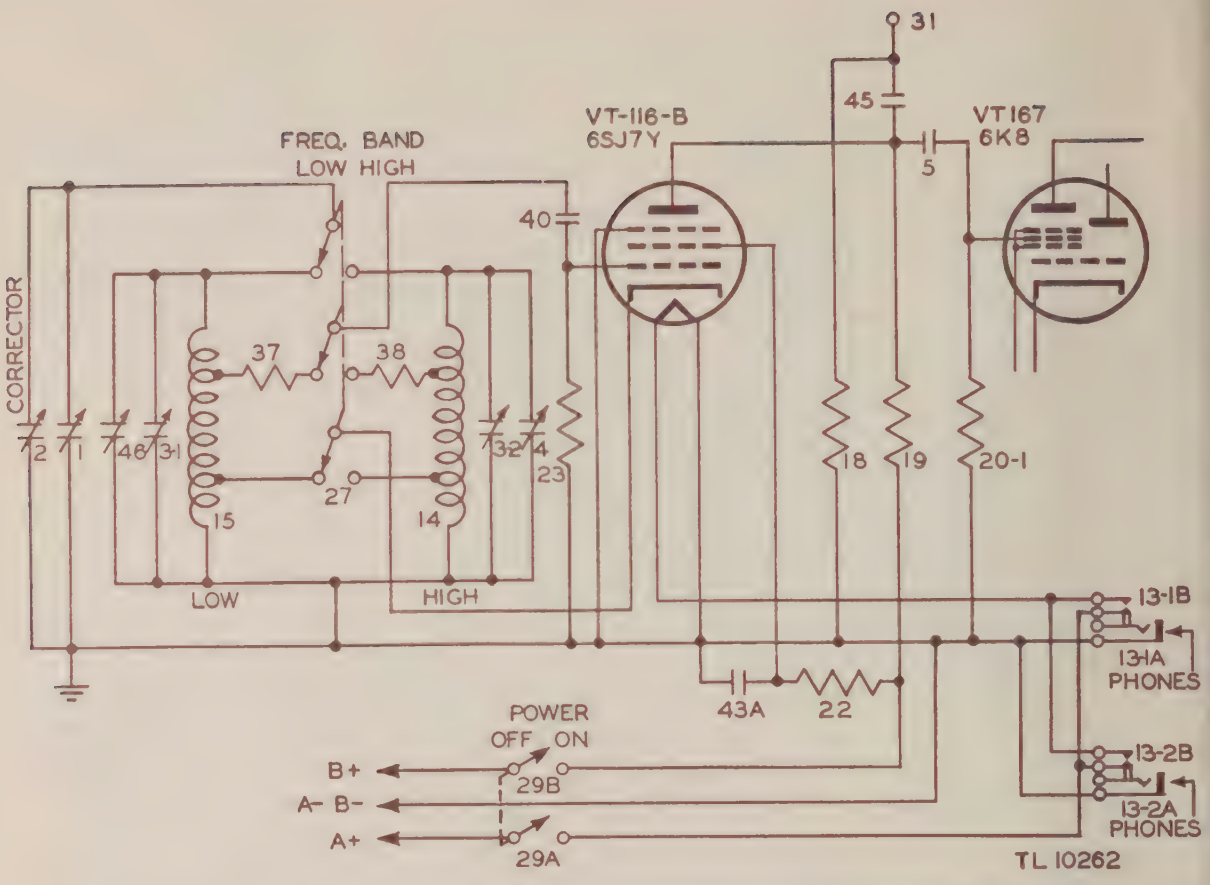


Figure 58. Frequency Meter BC-221-O, and BC-221-R, functional diagram, variable frequency oscillator circuit.

b. Band Selector Switch. (1) In Frequency Meter BC–221–M, the band selector switch 27 is a double-throw, four-pole switch. (See fig. 57.)

(2) In the BC–221–O and BC–221–R the band selector switch 27 is a double-throw, triple-pole switch. (See fig. 58.)

(3) In the BC–221–AC, the band selector switch 27 is a double-throw, six-pole switch. (See fig. 59.) Three sets of contacts on this switch are used to short-circuit the unused coil in order to prevent interaction between the two coils regardless of which one is in use.

(4) All contacts of these switches are mounted on ceramic plates. In order to minimize abnormal capacitive effects, all contacts are made as small as possible and are of the self-aligning, self-wiping type. Each switch has a heavy detent which accurately locates the rotor plate in either one of its two positions.

c. Corrector Control. Capacitor 2, the CORRECTOR control, with a range of 3 micromicrofarads ($3\mu\mu f$), enables the operator to control the variable capacitance of the tuned circuit in order to compensate for slight changes in the circuit. (See par. 154g.)

d. Trimming Capacitors. The trimming capacitors are parts 3–1 and 3–2 (parts 3–1a and 3–2a in the BC–221–AC). These are equipped with thermal compensator capacitors, parts 4 and 46 in the BC–221–O and BC–221–R, and parts 3–1b and 3–2b in the BC–221–AC. In the BC–221–M, thermal compensator capacitor 4 is connected directly across the main tuning capacitor 1 and compensates for either frequency range. Part 46, in this case, is used to detune the coil not in use in order to prevent interaction between the two coils. This arrangement (fig. 57) should be studied with care. The trimming capacitors are adjusted at the factory to build up the fixed capacitance of the LOW and HIGH frequency circuits to the exact values called for by the design of the variable tuning capacitor.

Caution: Do not tamper with these trimmer capacitor settings. To do so will throw the meter completely off calibration.

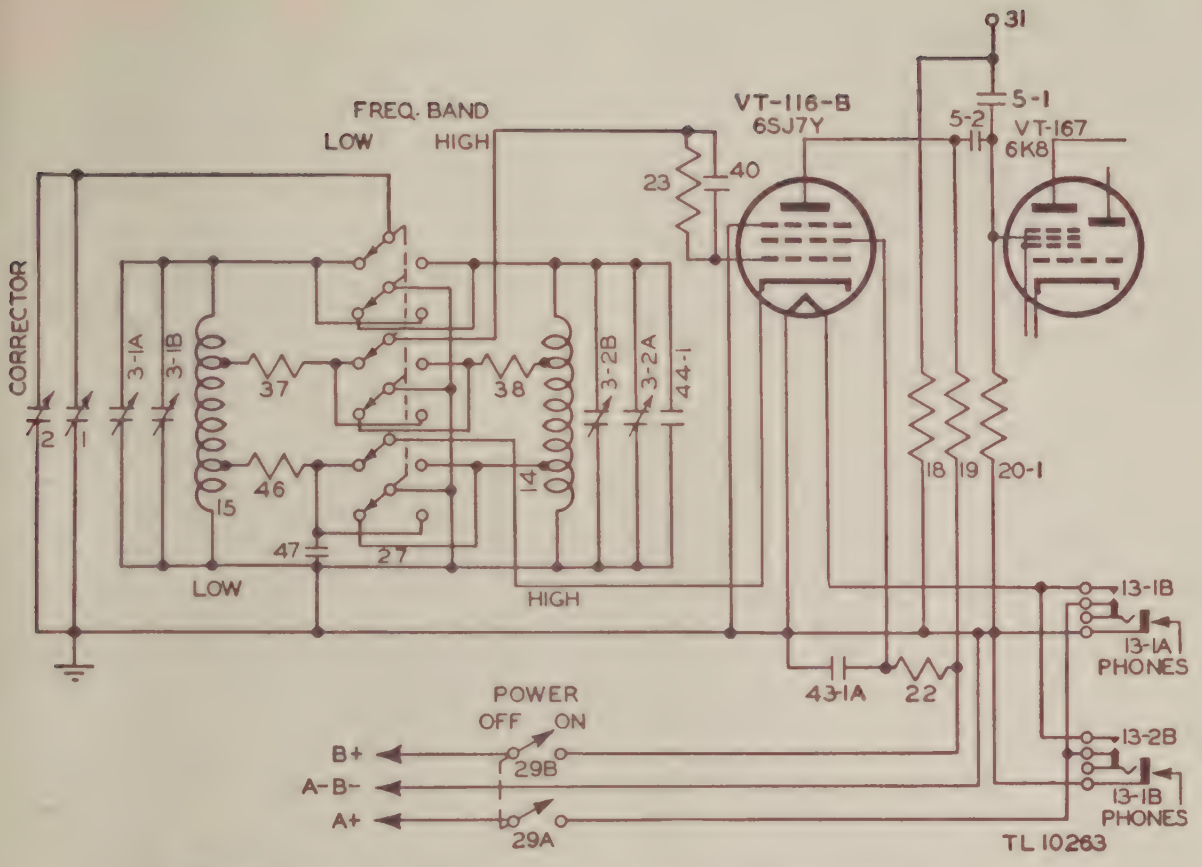


Figure 59. Frequency Meter BC–221–AC, functional diagram, variable frequency oscillator circuit.

e. Oscillator Function. (1) The variable frequency oscillator is in operation whenever the POWER switch 29 is in the ON position, the operation switch 28 is in either the HET. OSC. or XTAL CHECK position, and a headset is plugged into a PHONES jack. (See figs. 61, 62, and 63.)

(2) At the XTAL CHECK position of the operation switch 28, the output of oscillator Tube VT–116–B (6SJ7Y) is applied to the No. 3 grid of the hexode section of Tube VT–167 (6K8) where it is mixed with the output frequency of the crystal circuit. The result is a frequency equal to the difference of the two, and is used to adjust the frequency of the oscillator by means of the CORRECTOR control.

(3) At the HET. OSC. position of the operation switch 28, the variable frequency oscillator is in operation while the crystal oscillator is not. If the antenna is in position, the frequency meter may be used to receive or send any frequency in its range; that is, it may be used as a radio receiver or transmitter.

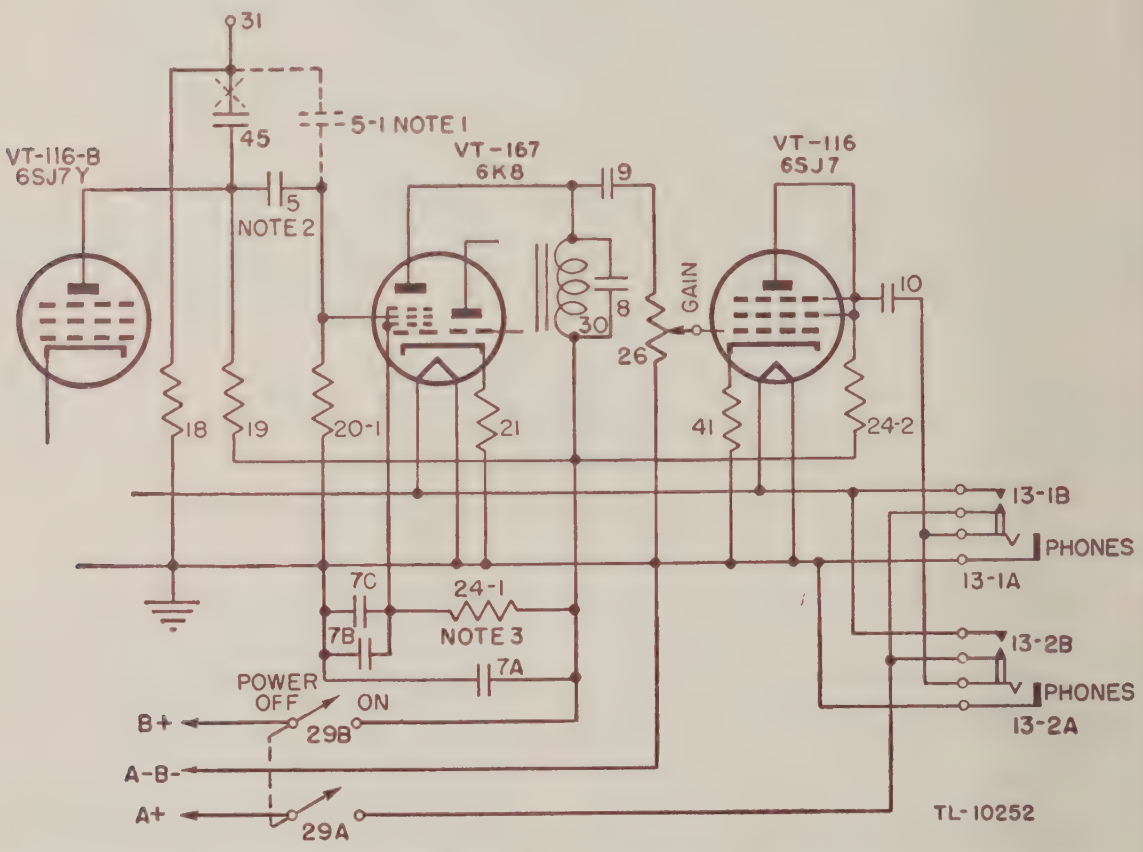
174. Detector Tube Circuit

It has been stated that the triode section of Tube VT-167 (6K8) is used in the crystal oscillator circuit. The remaining hexode section of the tube, of which the No. 1 grid is tied to the control grid of the triode section, is used as a high gain screen grid detector with hexode grid No. 3 acting as the control grid. The joint action of grids No. 1 and 3 produces electron coupling of the signals on the two grids. Resistor 20–1 is the detector tube grid leak. Resistor 24–1 supplies voltage to the screen grid of Tube VT–167 (6K8). Capacitors 7b and 7c, connected in parallel, bypass the screen grid to ground. (In the BC–221–AC, part No. 43–2b is the screen grid bypass capacitor.) Capacitor 7a is a bypass capacitance across the plate voltage (omitted in the BC–221–AC). Note that the antenna plug 31 is connected to ground through resistor 18. The r-f voltage developed across the load resistor 19 is in the plate output circuit of the variable frequency oscillator, is coupled to the No. 3 grid of this detector through a small fixed capacitor

5 (capacitor 5-2 in the BC–221–AC). The antenna plug 31 is also coupled to the No. 3 grid through the coupling capacitors 45 and 5 in series (through capacitor 5–1 alone in the BC–221–AC). As a result of these couplings to the control grid, the detector mixes the variable frequency oscillator output with the fundamental and successive harmonics of the crystal oscillator when the operation switch 28 is in the XTAL CHECK position, and with the radio transmitter frequency to be measured when the switch is in the HET. OSC. position. By reference to figure 60 it can be seen that the antenna plug 31 is also coupled to the variable frequency oscillator output through capacitor 45 in the BC–221–M, BC–221–O, and BC–221–R and through capacitors 5–1 and 5–2, in series, in the BC–221–AC. Thus, the antenna connection serves the dual purpose of a detector input terminal for the measurement of frequencies of external origin and of a variable frequency oscillator output terminal for use in calibrating receivers. When the unit is employed for the latter purpose, a minimum of 2,000 micro-volts of radio frequency energy will be available between the antenna terminal and ground (the chassis) at any frequency within the calibrated range.

175. Audio-Amplifying Circuit (par. 25)

The detector plate works into an audio-frequency choke coil 30, which is bypassed by the capacitor 8 to reduce the response to high frequencies. The beat frequency voltages built up across the choke coil are coupled through capacitor 9 and the GAIN control potentiometer 26 to the grid of Tube VT–116 (6SJ7), connected as a triode. The grid of Tube VT–116 returns to ground through the potentiometer 26, and the necessary grid bias voltage is obtained by



NOTE 1: CONNECTION SHOWN DASHED AND OPEN CIRCUIT SHOWN APPLIES TO BC-221-AC ONLY.
NOTE 2: PART NO. 5-2 IN THE BC-221-AC
NOTE 3: PART NOS. 7B AND 7C ARE REPLACED BY PART NO. 43-2B, AND PART NO. 7A IS OMITTED IN THE BC-221-AC

Figure 60. Frequency Meter BC–221–(4), functional diagram, detector and audio-amplifier circuits.

means of the cathode dropping resistor 41. The plate (tied to the suppressor and screen grids) of Tube VT–116 returns to the positive plate supply voltage through the plate load resistor 24–2. The plate of this tube is coupled also to the PHONES jacks 13–1a and 13–2a through capacitor 10, so that no d–c voltage will be present in the output circuit. The characteristics of the output circut are such that either high-impedance (15,000 ohms) or low-impedance (2,500 ohms) headsets may be used without any change-over adjustments being necessary.

176. Power Supply Circuit (figs. 61, 62, and 63)

All power required for the operation of the meter is introduced through the battery terminal board 36, located at the end of the battery cable. The common negative filament and negative plate battery leads are connected to the middle terminal which is grounded to the chassis. A fabricated wiring harness is provided for intercell and filament battery to terminal board connections in the BC–221–M, BC–221–O, and BC–221–R, while a fiber terminal board is added for use in the BC–221–AC. Section 29a of the POWER switch closes the positive 6-volt supply terminal (A+) to the vacuum tube filaments through the auxiliary switches 13–1b and 13–2b on the PHONES jacks 13–1a and 13–2a when a headset plug is inserted in one of the jacks; whereas section 29b connects the positive 135-volt terminal (B+) to all plate and screen circuits. Since the door covering the control panel cannot be closed with the headset plug in place, the *A* and *B* batteries cannot be discharged even though the POWER switch is left in the ON position when the meter is removed from service.

Section IV. MAINTENANCE

177. General

For all details of field maintenance, see paragraphs 26, 27, and 28.

Section V. SUPPLEMENTARY DATA

178. Tabular List of Maintenance Parts

a. Frequency Meter BC–221–M.

Note. Order maintenance parts by stock number, name, and description.

Ref. No. symbol	Signal Corps stock No.	Name of part and description	Quan. per equip.	Lowest maint. echelon
	2Z481D.....	BAG: BG–81–D; carrying.....	1....	3d
	2Z551–160...	BAG: BG–160–(&)/S; available for amphibious operations.....	1....	Orgn stock
	3A2.....	BATTERY: BA2; 22.5=v.....	6....	3d
	3A23.....	BATTERY: BA23; 1.5=v.....	4....	3d
	3E1605–6.5...	CORD: CD–605; 6½=ft; 2=cond.; PL–55 at one end; Transformer C–410 at other.	1....	3d
	3E1874.....	CORD: CD–874; 6½=ft; 2=cond.; PL–55 on one end; JB–47 on other end.....	1....	3d
	2B830(&).....	HEADSET: HS–30–(&); component HEADSET: HS–30–(&); repair parts } ...	1....	Orgn stock
	2B1300.....	INSERT: M–300.....	2....	Orgn stock
	2Z9019A.....	STRAP: ST–19–A.....	1....	3d

b. FREQUENCY METERS BC–221–O AND BC–221–R.

NOTE. Order maintenance parts by stock number, name, and description.

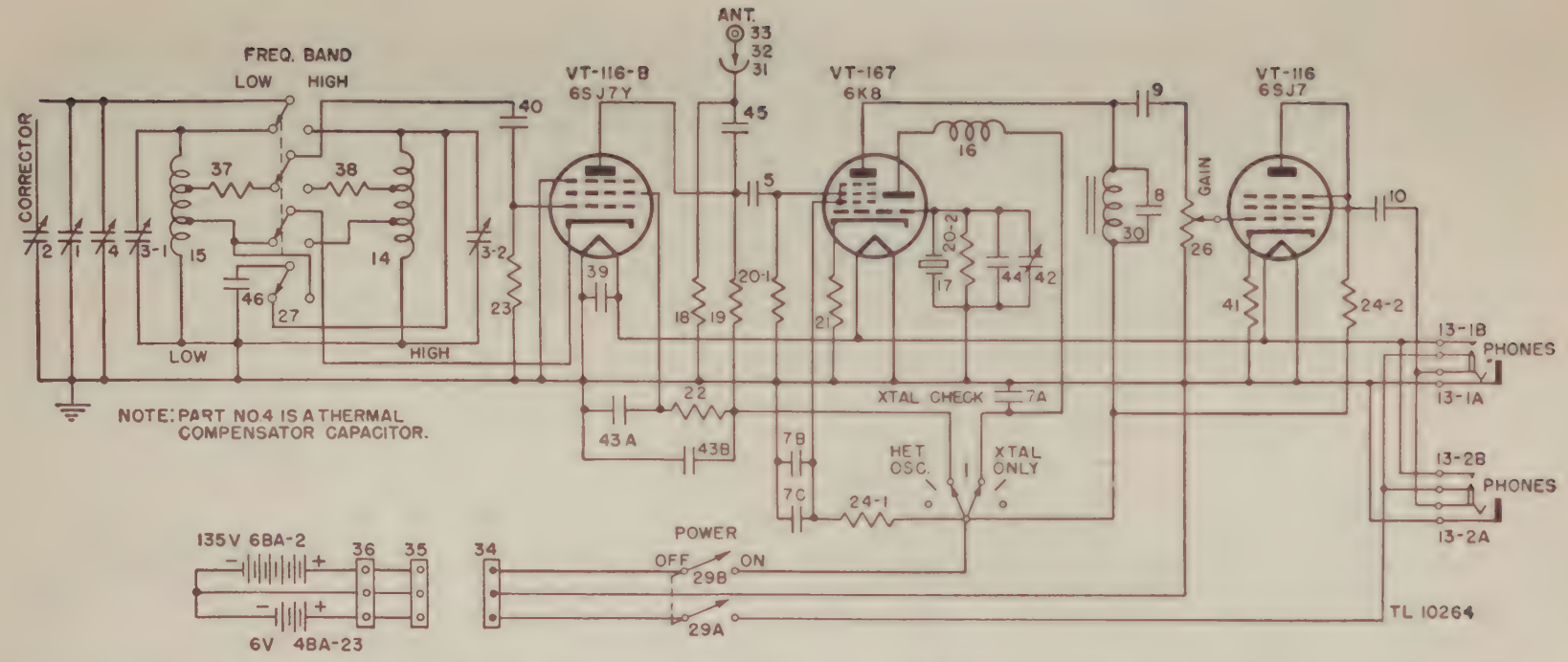
Ref. No. symbol	Signal Corps stock No.	Name of part and description	Quan. per equip.	Lowest maint. echelon
	2Z4810 2Z481R	BAG: BG–81–O; carrying BAG: BG–81–R; carrying	1* 1*	3d
	2Z551–160	BAG: BG–160–(&)/S; available for amphibious operations	1	Orgn stock
	3A2	BATTERY: BA2; 22.5=v	6	3d
	3A23	BATTERY: BA23; 1.5=v	4	3d
	3E1605–6.5	CORD: CD–605; 6½=ft; 2=cond.; PL–55 at one end; Transformer C–410 at other	1	3d
	3E1874	CORD: CD–874; 6½=ft; 2=cond.; PL–55 on one end; JB–47 on other end	1	3d
	2B830(&)	HEADSET: HS–30–(&); component HEADSET: HS–30–(&); repair parts	1	Orgn stock
	2B1300	INSERT: M–300	2	Orgn stock
	2Z9019A	STRAP: ST–19–A	1	3d

* Only one Bag BG–81–O or BG–81–R is furnished per equipment.

c. FREQUENCY METER BC–221–AC.

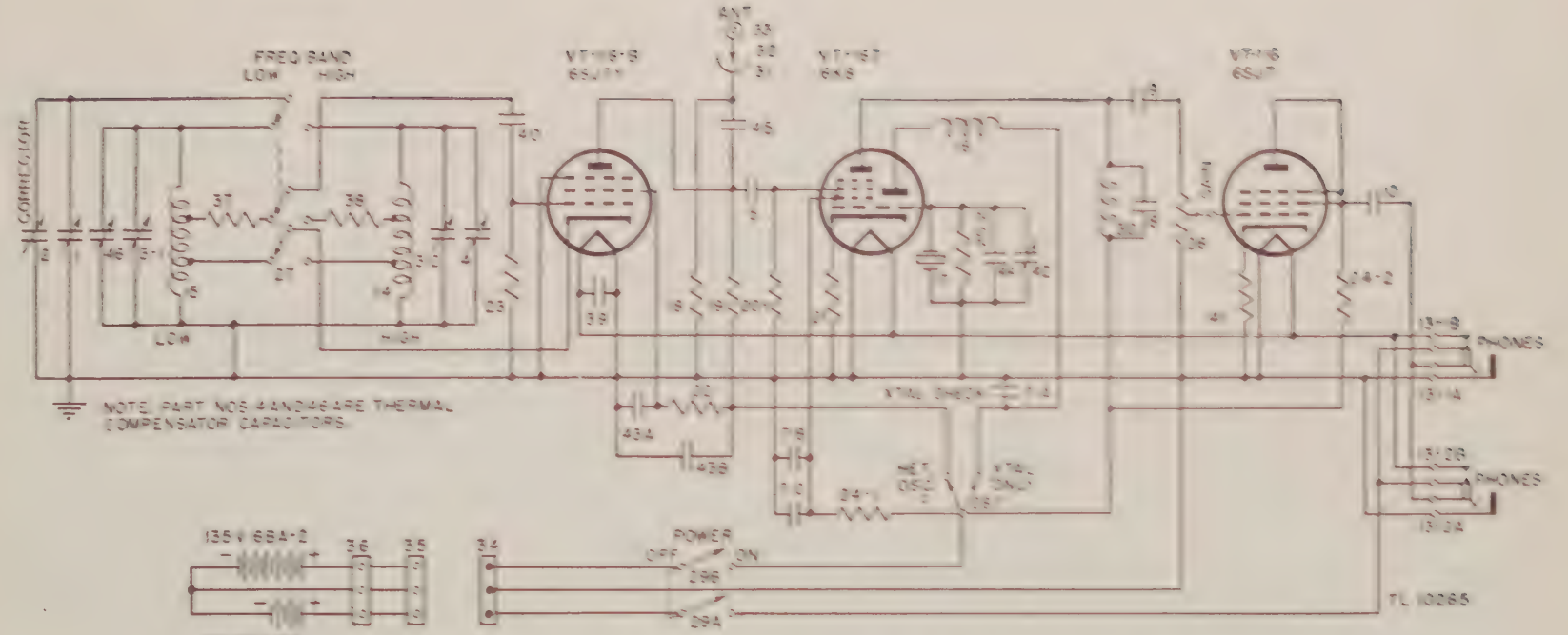
NOTE. Order maintenance parts by stock number, name, and description.

Ref. No. symbol	Signal Corps stock No.	Name of part and description	Quan. per equip.	Lowest maint. echelon
	2Z481AC	BAG: BG–81–AC; carrying	1	3d
	2551–160	BAG: BG–160–(&)/S; available for amphibious operations	1	Orgn stock
	3A2	BATTERY: BA2; 22.5=v	6	3d
	3A23	BATTERY: BA23; 1.5=v	4	3d
	3E1605–6.5	CORD: CD–605; 6½=ft; 2=cond.; PL–55 at one end; Transformer C–410 at other	1	3d
	3E1874	CORD: CD–874; 6½=ft; 2=cond.; PL–55 on one end; JB–47 on other end	1	3d
	2B830(&)	HEADSET: HS–30–(&); component HEADSET: HS–30–(&); repair parts	1	Orgn stock
	2B1300	INSERT: M–300	2	Orgn stock
	2Z9019A	STRAP: ST–19–A	1	3d



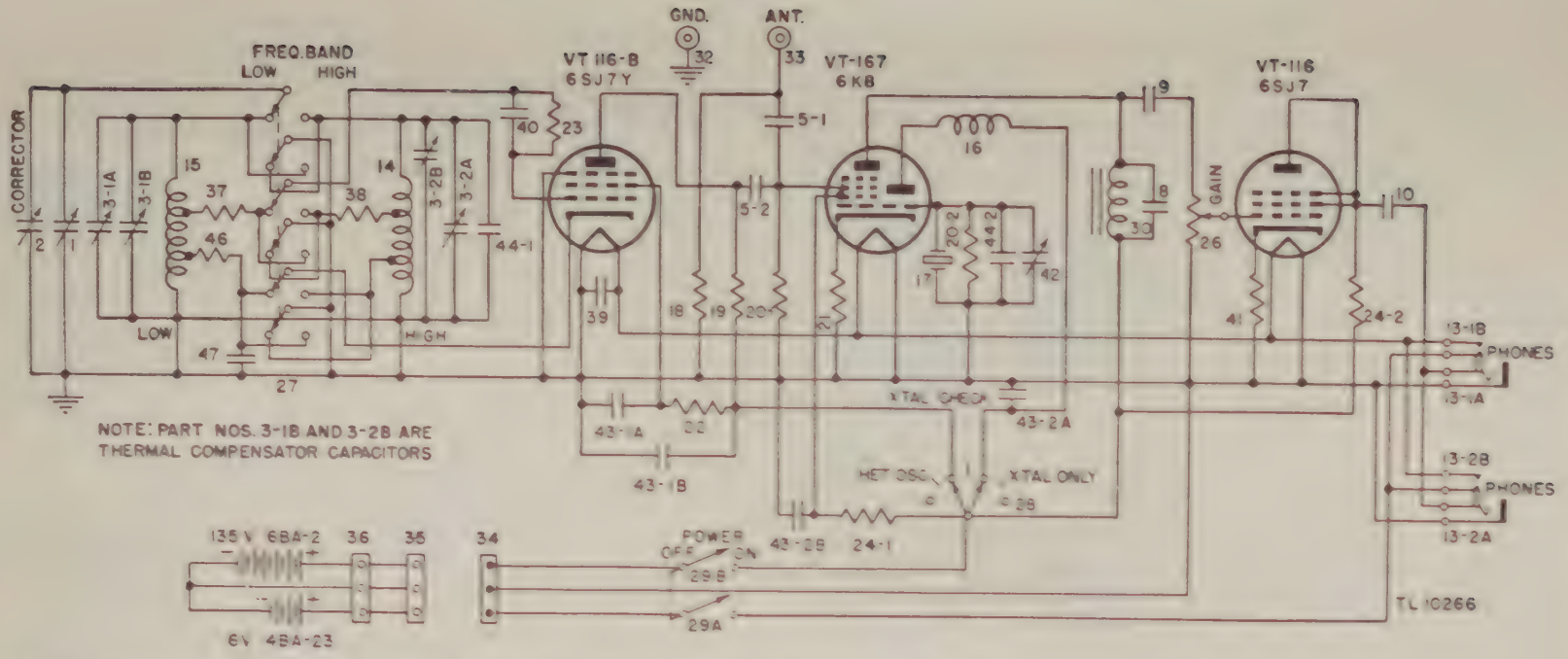
REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	160 μμf	13–1A	JACK	19	56,000 OHM	29	SWITCH	38	100 OHM
2	3 μμf	13–1B	FIL. SWITCH	20–1&2	1 MEGOHM	30	450 HENRYS	39	.001 μf
3–1&2	10 μμf	13–2A	JACK	21	150 OHM	31	ANT. PLUG	40	100 μμf
4	5 μμf	13–2B	FIL. SWITCH	22	9,100 OHM	32	CONTACT SPRING	41	300 OHM
5	8 μμf	14	36.5 MICROHY	23	150,000 OHM	33	BINDING POST	42	12 μμf
7A,B,C	0.1 μf	15	10.4 MILLIHY	24–1&2	15,000 OHM	34	POWER PLUGS	43A,&B	0.1 μf
8	.001 μf	16	844 MICROHY	26	0.5 MEGOHM	35	POWER JACKS	44	5 μμf
9	.02 μf	17	CRYSTAL	27	SWITCH	36	BATTERY TERM	45	15 μμf
10	0.5 μf	18	5,600 OHM	28	SWITCH	37	7,500 OHM	46	47 μμf

Figure 61. Frequency Meter BC–221–M, schematic diagram.



REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	.170 $\mu\mu f$	13-1A	JACK	19	56,000 OHM	29	SWITCH	38	100 OHM
2	3 $\mu\mu f$	13-1B	P.L. SWITCH	20-1&2	1 MEGOHM	30	450 HENRYS	39	.05 μf
3-1&2	10 $\mu\mu f$	13-2A	JACK	21	150 OHM	31	ANT. PLUG	40	100 $\mu\mu f$
4	12 $\mu\mu f$	13-2B	P.L. SWITCH	22	9,100 OHM	32	CONTACT SPRING	41	300 OHM
5	10 $\mu\mu f$	14	HIGH FREQ. COIL	23	150,000 OHM	33	BINDING POST	42	.01 μf
7-A,B,C	0.1 μf	15	LOW FREQ. COIL	24-1&2	15,000 OHM	34	POWER PLUGS	43 A&B	0.1 μf
8	.001 μf	16	R.F. CHOKE COIL	26	0.5 MEGOHM	35	POWER JACKS	44	8 μf
9	.02 μf	17	CRYSTAL	27	SWITCH	36	BATTERY TERM.	45	15 μf
10	0.5 μf	18	5,600 OHM	28	SWITCH	37	7,500 OHM	46	4 μf

Figure 66. Frequency Meters BC-221-O and BC-221-R, Schematic Diagram



REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	170 μμf	13-1A	JACK	20-1&2	1 MEGOHM	38	BINDING POST	47	
2	3 μμf	13-1B	FIL. SWITCH	21	150 OHM	39	BINDING POST	48-1A	
3-1A	10 μμf	13-2A	JACK	22	6,000 OHM	40	POWER PLUGS	48-2B	
3-1B	7 μμf	13-2B	FIL. SWITCH	23	150,000 OHM	41	POWER JACKS	48-2A	
3-2A	10 μμf	14	36.6 MICROHM	24-1&2	10,000 OHM	42	BATTERY TERM	48-2B	
3-2B	7 μμf	15	117.4 MICROHM	25	0.5 MEGOHM	43	1,500 OHM	49-1&2	
5-1&2	25 μμf	16	644 MICROHM	26	SWITCH	44	100 OHM	49	
6	.001 μf	17	CRYSTAL	28	SWITCH	45	.05 μf	47	
9	.02 μf	18	5,600 OHM	29	SWITCH	46	1.0 μf		
10	0.5 μf	19	50,000 OHM	30	450 HENRYS	47	800 OHM		

Figure 63. Frequency Meter BC-221-AC, schematic diagram.

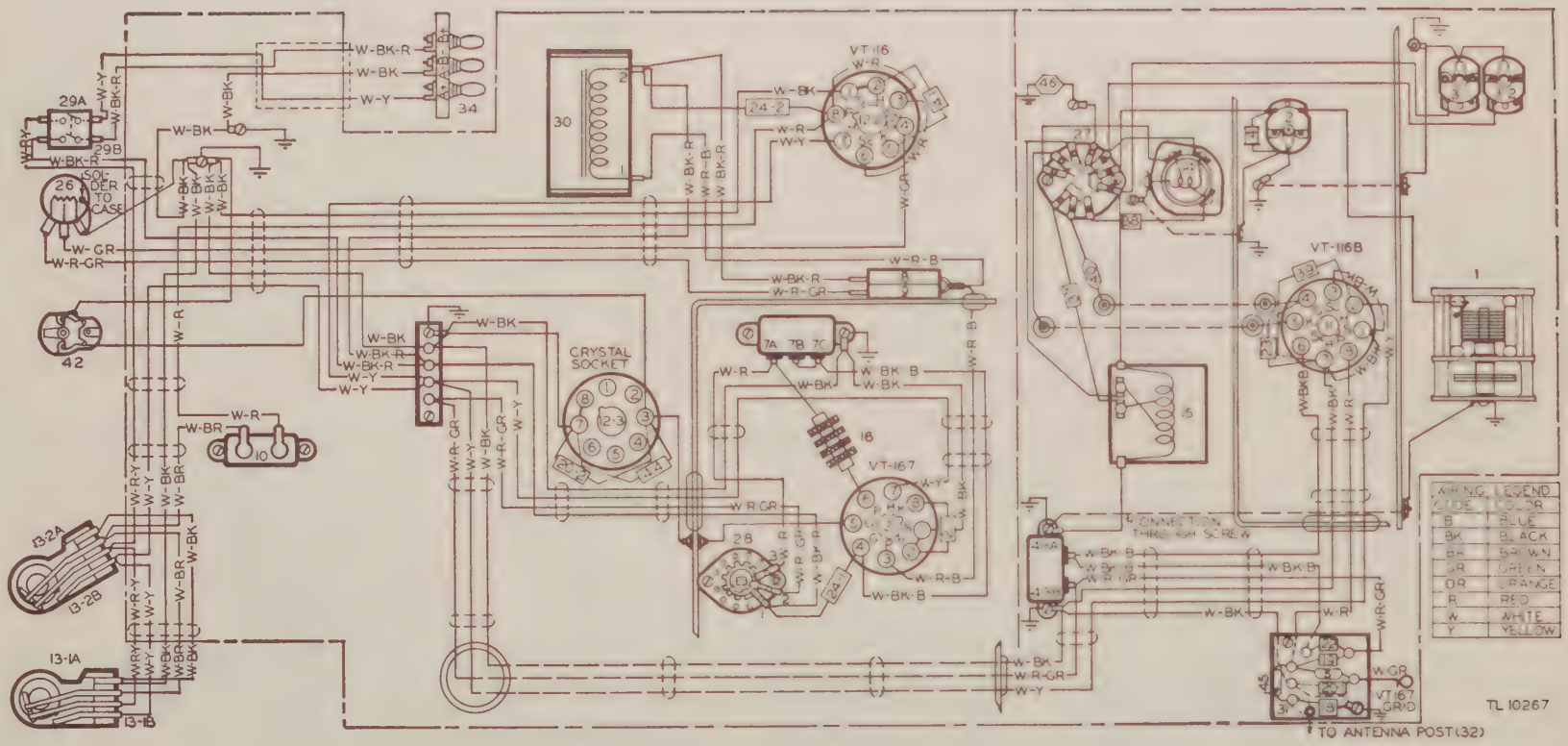


Figure 64. Frequency Meter BC–221–M, chassis wiring diagram.

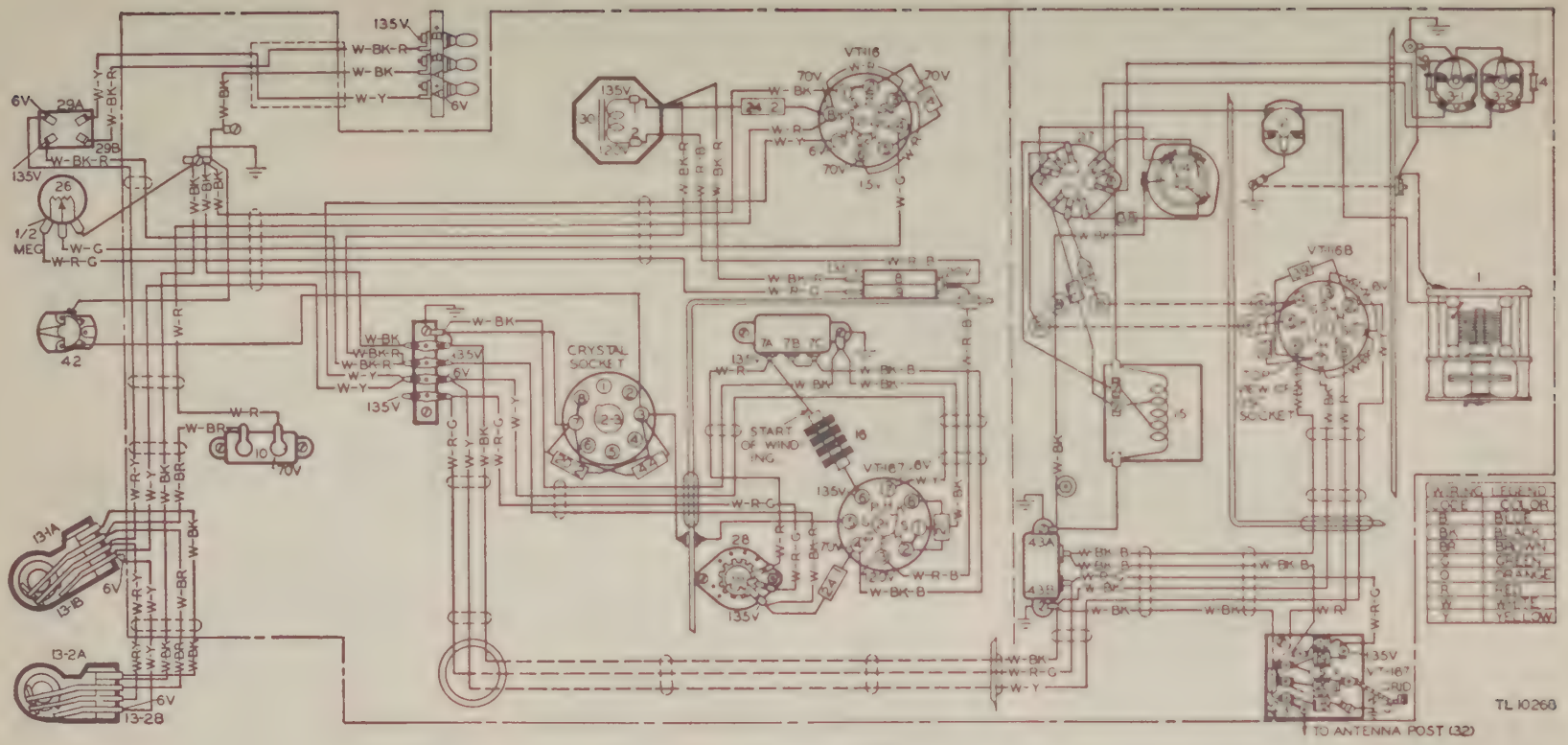


Figure 65. Frequency Meters BC-221-O and BC-221-R, chassis wiring diagram.

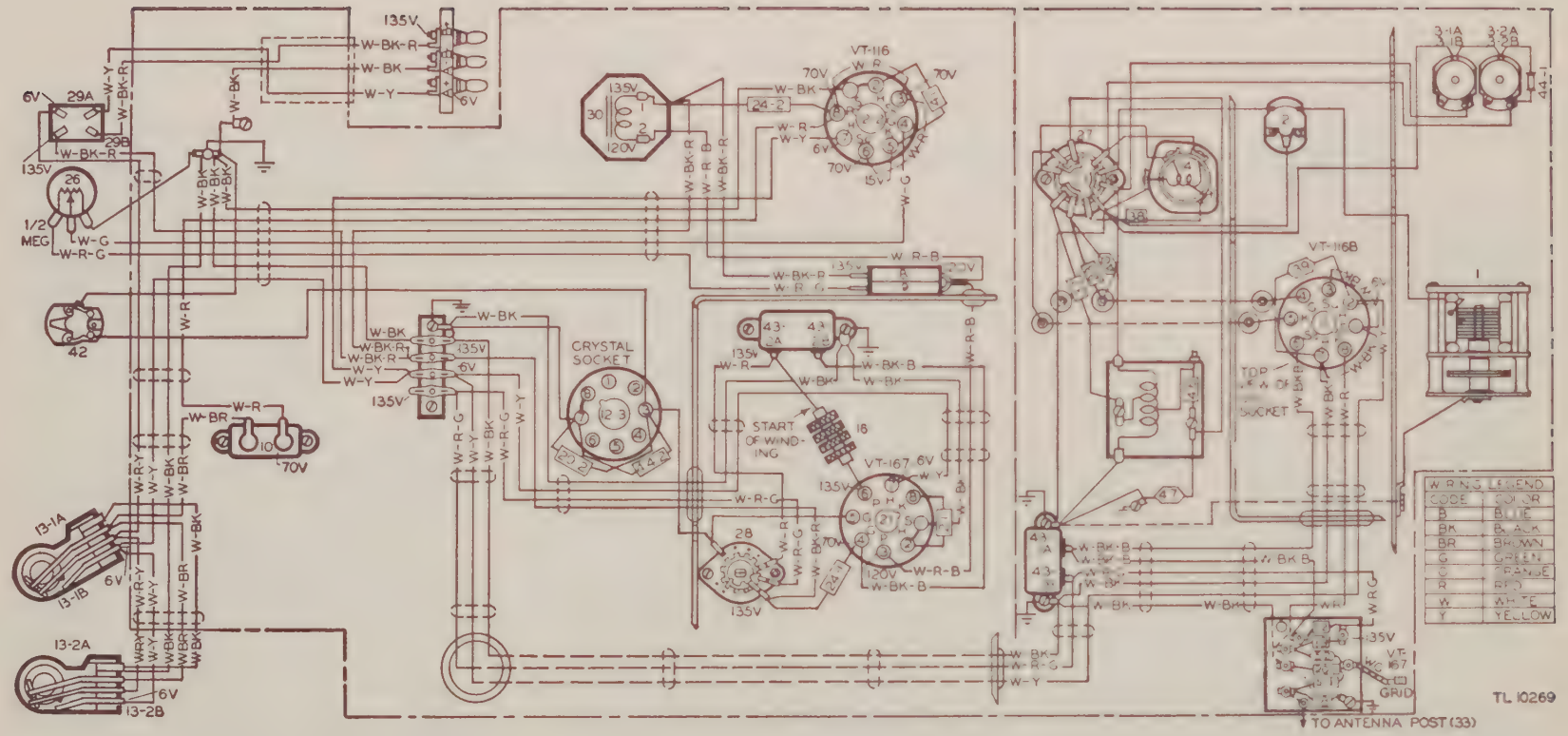


Figure 66. Frequency Meter BC–221–AC, chassis wiring diagram.

CHAPTER 7

FREQUENCY METER SETS SCR–211–N AND SCR–211–AA

Section I. DESCRIPTION

179. General

Frequency Meter Sets SCR–211–N and SCR–211–AA have been manufactured by the Philco Corporation on several orders. These two models are essentially alike in all important details, except for the fact that early models of the SCR–211–N (serial Nos. 1 through 3800) differ from later models of the SCR–211–N (serial Nos. 3801 and up) and the SCR–211–AA. The later models of the SCR–211–N and the SCR–211–AA are exactly alike electrically. The SCR–211–AA is supplied in two types of cases, metal and wooden, which causes some differences in weight as well as in the list of components furnished. These differences are discussed in detail in applicable parts of this chapter. For further general information see paragraph 2. The symbol (5) as used in this chapter refers to either the SCR–211–N or SCR–211–AA.

180. Components

Each Frequency Meter Set SCR–211–(5) includes the following component units:

Quantity	Component
1.....	Frequency Meter BC.221.(5) includes:
	1 Crystal Unit DC–9–P or DC–9–AD (in operating position)[1].
	1 Crystal Unit DC–9–P or DC–9–AD (spare, mounted on chassis)[2].
	1 Calibration Book MC–117–(5).
	1 Wrench for Bristo No. 8 setscrew (spares compartment).
4.....	Tube VT–116 type 6SJ7 (two in use, two spare).
2.....	Tube VT–167 type 6K8 (one in use, one spare).
1.....	Bag BG–81–(5)[3].
2.....	TM 11–300–(5) for Frequency Meter Set SCR–211–(5).
1.....	Strap ST1–9–A.

1 Any crystal unit with nomenclature N or higher can be used interchangeably with any frequency meter set with nomenclature N or higher.

2 Not included with the SCR–211–AA.

3 A bag is not furnished with the SCR–211–AA with wooden case. A suitable canvas cover is supplied with the wooden case and is not considered to be a separate component.

181. Additional Equipment Required

The following equipment, not furnished with the orders, is required to complete each Frequency Meter Set SCR–211–(5):

Quantity	Article
1.....	Headset HS–30–(&) with Cord CD–605*.
6.....	Batteries BA–2.
4.....	Batteries BA–23.

* If this headset and cord cannot be obtained, use Headset P–18 or P 20.

182. Total Weight

Frequency Meter Set SCR–211–(5), complete and ready for service, weighs as follows: SCR–211–N, serial Nos. 1 through 3800, 35.82 pounds; SCR–211–N, serial Nos. 3801 and up, 36.42 pounds; SCR–211–AA, with metal case, 35.4 pounds; SCR–211–AA, with wooden case, 35.8 pounds. For typical dimensions, see figures 26 and 27.

183. Power Consumption

All power required for the operation of this equipment is supplied by the batteries listed in paragraph 181. The current drains under the specified conditions are approximately as follows:

Filaments: 6 volts; 0.85 ampere.
Plates, etc.: 135 volts;
0.012 ampere with operation switch at CRYSTAL.
0.018 ampere with operation switch at OPERATE.
0.014 ampere with operation switch at CHECK.

NOTE. Contrary to the general rule covering this type of meter, the SCR–211–(5) places maximum load on the batteries in the OPERATE position of the operation switch.

184. Controls (pars. 2e and 94)

185. Vacuum Tubes

The vacuum tubes used in the Frequency Meter Set SCR–211–(5) are shown in the following tabulation:

Reference	Function	Signal Corps type nomenclature	Commercial equivalent	Base
VT 116.....	Variable frequency oscillator	VT 116.....	6SJ7	Octal
VT 167.....	Crystal oscillator and detector.	VT 167.....	6K8	Octal
VT 116.....	Audio-frequency amplifier.	VT 116.....	6SJ7	Octal

Section II.
INSTALLATION AND OPERATION

186. Initial Procedure (par. 7)

Make sure a spare set of vacuum tubes is installed in the spare parts compartment.

187. Installation of Batteries

See paragraph 8, and then proceed as follows:

a. For the BC–221–N and the BC–221–AA with metal case, follow the directions given in paragraph 38.

b. For the BC–221–AA with wooden case, proceed as follows: remove the frequency meter chassis from the cabinet while the batteries are being installed. Open the battery compartment in the lower rear portion of the cabinet by turning the two fasteners one half turn to the left with a coin or screwdriver. Place the four Batteries BA–23 in the right-hand portion of the compartment with their terminal posts facing the rear of the cabinet. Then connect the six Batteries BA–2 in series and insulate the splices with friction tape or spaghetti so as to prevent short

circuits. Assemble the six batteries in two layers of three each with the top layer inverted. See that the minus and plus 135-volt leads are free for connection to their respective terminals on the terminal board. Insert the batteries in the cabinet and connect them to the terminal board. Arrange the four Batteries BA–23 so that their terminals can be connected by means of the fiber terminal board placed over them as shown in figure 67. After installing the battery terminal nuts and securing the positive and negative harness leads, install the 3/8-inch wood spacer and secure with the bolt provided to prevent short-circuiting the batteries. (See fig. 11.)

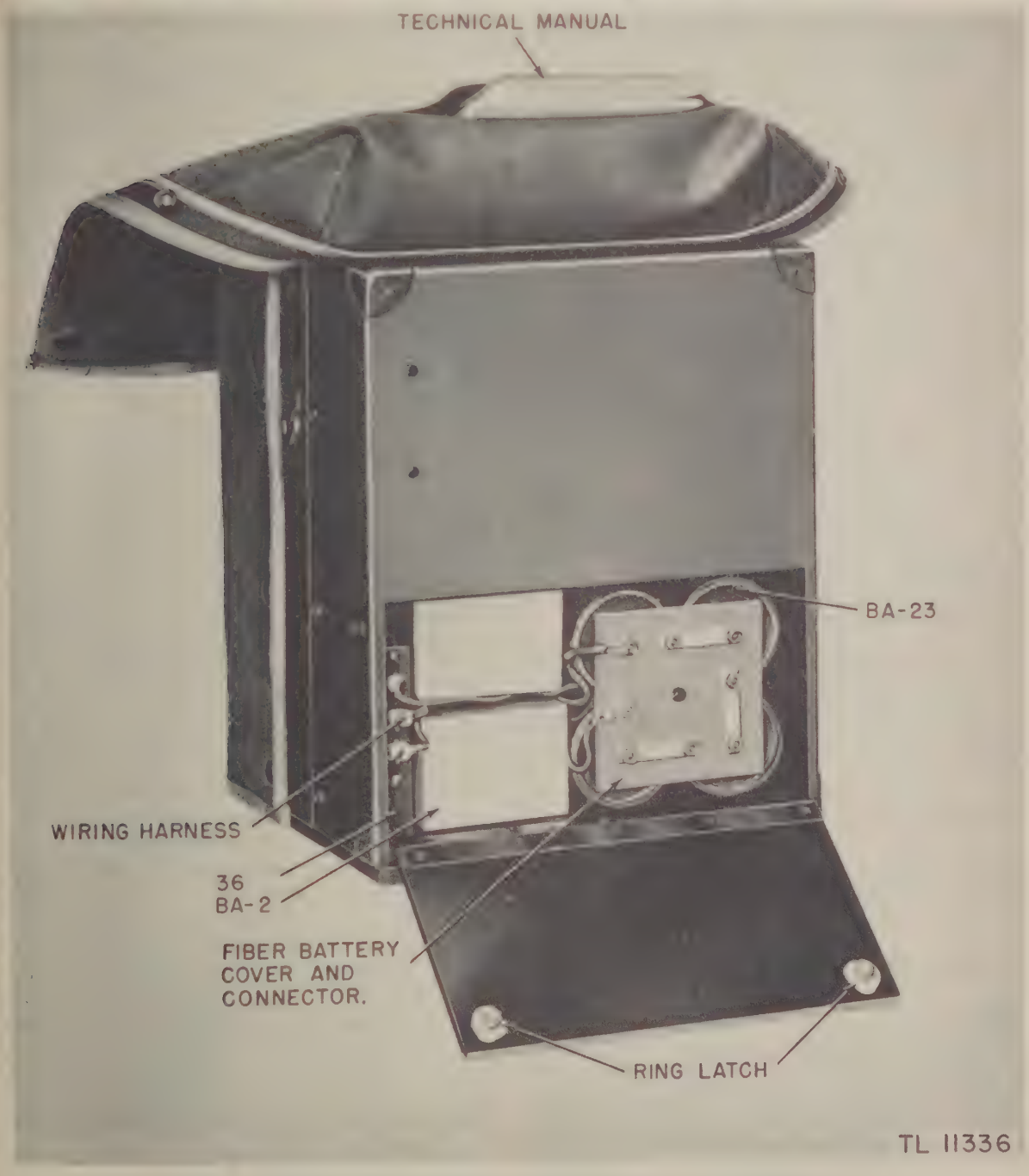


Figure 67. Frequency Meter BC–221–(&), wooden cabinet, battery installation.

Caution: Do not touch the connecting leads when batteries are being loaded into the battery compartment. A severe shock may result. Do not short-circuit the terminals of the terminal board while making connections.

c. After replacing the frequency meter chassis, check the battery installation as indicated in paragraph 8*d* with the operation switch in the OPERATE position.

188. Antenna (par. 9)

189. Headset (par. 10)

A headset plug must be inserted in one of the PHONES jacks before the meter will operate.

190. Preparation for Use (par. 70)

191. Reading the Dial (par. 11)

192. Calibration Book MC–177–(5) (par. 12)

193. Operating Circuits (par. 13)

194. Zero Beat Detection (par. 14)

195. Correction in Calibration (par. 15)

The information contained there applies exactly to Frequency Meter BC–221–(5).

196. Crystal Check Points (par. 16)

197. Frequency Measurements (par. 17)

The proper position of the operation switch of the BC–221–(5) is OPERATE for making frequency measurements as described in paragraph 17.

198. Precautions During Operation (par. 18)

199. Adjustments for Field Upkeep (par. 19)

Section III. FUNCTIONING OF PARTS

200. General

As stated in paragraph 179, the early models of Frequency Meter BC–221–N differ from the later version of the same meter as well as from the BC–221–AA. Beginning with the equipment serial No. 3801, Frequency Meter BC–221–N incorporates additional temperature compensating devices as well as other changes in internal construction. Some parts intended for use in Frequency Meter BC–221–N, serial Nos. 1 through 3800, may not function satisfactorily in meters having serial Nos. 3801 and higher. Part Nos. 5 and 37 differ slightly in electrical characteristics. The schematic diagram (fig. 71) indicates that it is not necessary to show separate functional diagrams on the two types of meters since the main difference consists of the temperature compensating devices.

201. Circuit Components (par. 21)

202. Crystal Circuit

The crystal circuit uses the triode section of Tube VT–167 (6K8) shown in figure 68. The oscillator operates at the fixed frequency of 1,000 kc when operation switch 28 is placed in the CRYSTAL or CHECK position. The operation switch controls the crystal oscillator by opening or closing its plate voltage circuit. The oscillator circuit is designed to generate considerable harmonic energy so that it can be used to calibrate the variable frequency oscillator at several points over its entire range, as well as supply whole multiples of 1,000 kc for the calibration of receivers and similar equipment. The necessary plate circuit impedance is built up across choke coil 23, shunted by capacitor 4–c, to provide a low impedance path to ground for high order harmonics of the crystal oscillator fundamental frequency (1,000 kc). Resistor 20–2 is the oscillator grid leak and works in conjunction with tube cathode resistor 39. Variable capacitor 37 is connected across crystal 25 for the purpose of adjusting the frequency of the crystal to a closer point than can be economically obtained by grinding alone. When the frequency meters are adjusted during manufacture, the variable capacitor is set up to produce a frequency of 1,000 kc ± 5 cycles at 20° centigrade. Fixed capacitor 5, shunted across the crystal, minimizes any change in fundamental frequency due to small changes in the crystal capacitance. Further reference to figure 68 shows that the output of the crystal oscillator is electron coupled to the antenna through the No. 3 grid of the hexode section of Tube VT–167 (6K8) and capacitor 8–1. For further details on the crystal oscillator, see paragraph 22.

203. Variable Frequency Oscillator Circuit (par. 23)

Tube VT–116 (6SJ7) is used as an electron coupled circuit as the variable frequency oscillator. (See fig. 69.)

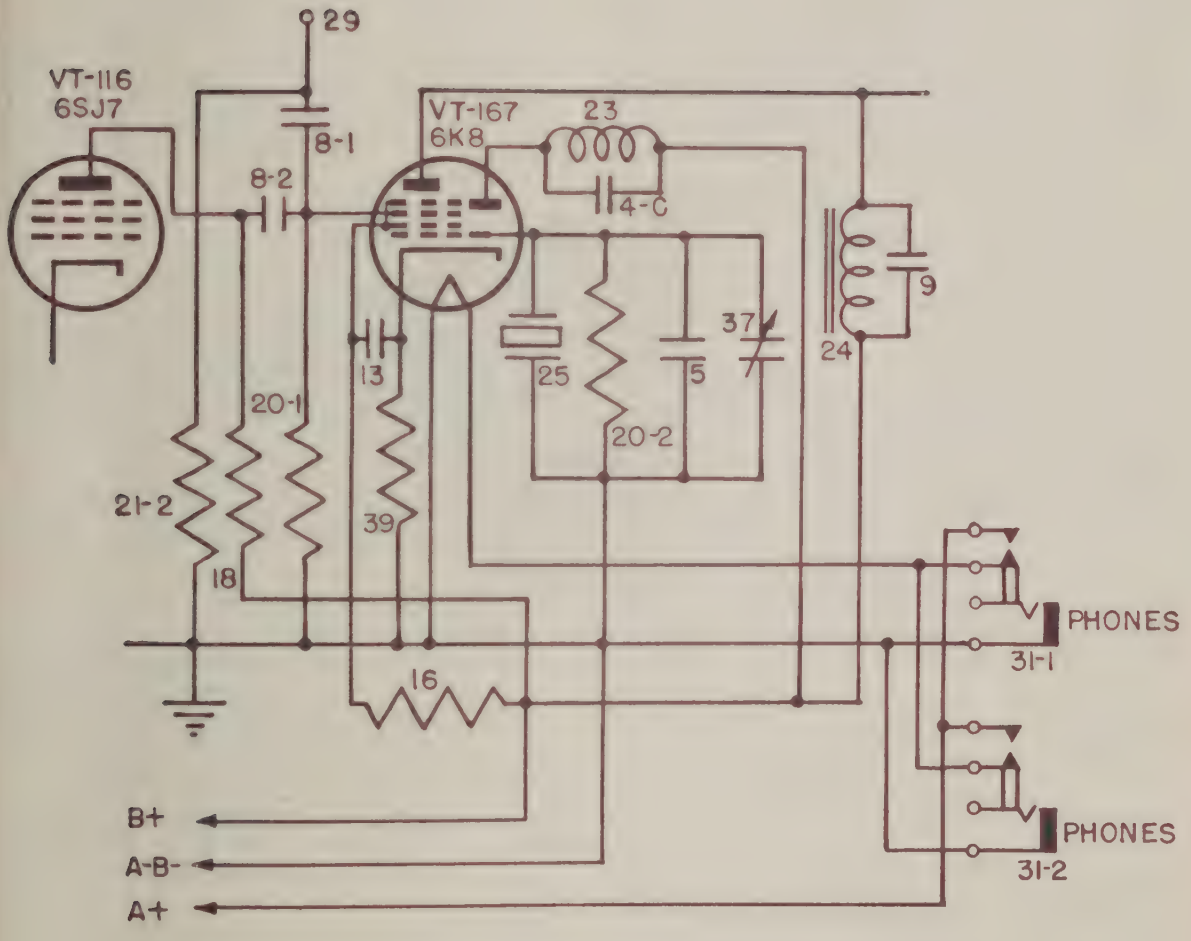


Figure 68. Frequency Meter BC-221-(5), functional diagram, crystal-oscillator circuit.

a. Coils. The two inductors 22 and 30 in the tuned circuits are wound upon ceramic forms and LOW frequency coil 30 is coated with a special wax to eliminate the influence of changing atmospheric conditions on the stability of the meter. The active terminals of these coils are connected across the terminals of main tuning capacitor 1 by means of band selector (FREQ. BAND LOW-HIGH) switch 27. Each coil and the tuning capacitor, together with other capacitors mentioned below, constitute the resonant circuit that determines the output frequency. The correct operating bias on the control grid of the oscillator tube is provided by the capacitor and resistor combination 7 and 19, which connects to a tap on either coil through band selector switch 27. The frequency of oscillation is made relatively independent of variations in tube characteristics when the grid connection is tapped down an appreciable distance from the high-potential end of the coil. Resistors 14 and 15, which carry little current, are connected in series with the grid circuit taps on the coils, and serve to stabilize the operation of the oscillator circuit by suppressing undesirable oscillations. The second coil tap, located near the grounded end of each coil, and connected to the cathode of the oscillator tube through another set of contacts on switch 27, serves to control the amount of feedback in the oscillator circuit. Resistor 21–1, which is in series with this connection on coil 30, applies additional cathode bias to the grid of the oscillator tube. This cathode bias resistor is bypassed to ground by capacitor 6. The short-circuited windings shown at the end of each of the coils in figure 69 are the temperature compensating devices added to the BC–221–N and used in the BC–221–AA. Resistor 18 is the oscillator tube plate circuit load. The voltage developed across it is coupled to detector-converter Tube VT–167 through capacitor 8–2, or the antenna through capacitors 8–2 and 8–1 in series. Resistor 38 is the screen grid dropping resistor, and part 10–2 is the screen grid bypass capacitor to ground.

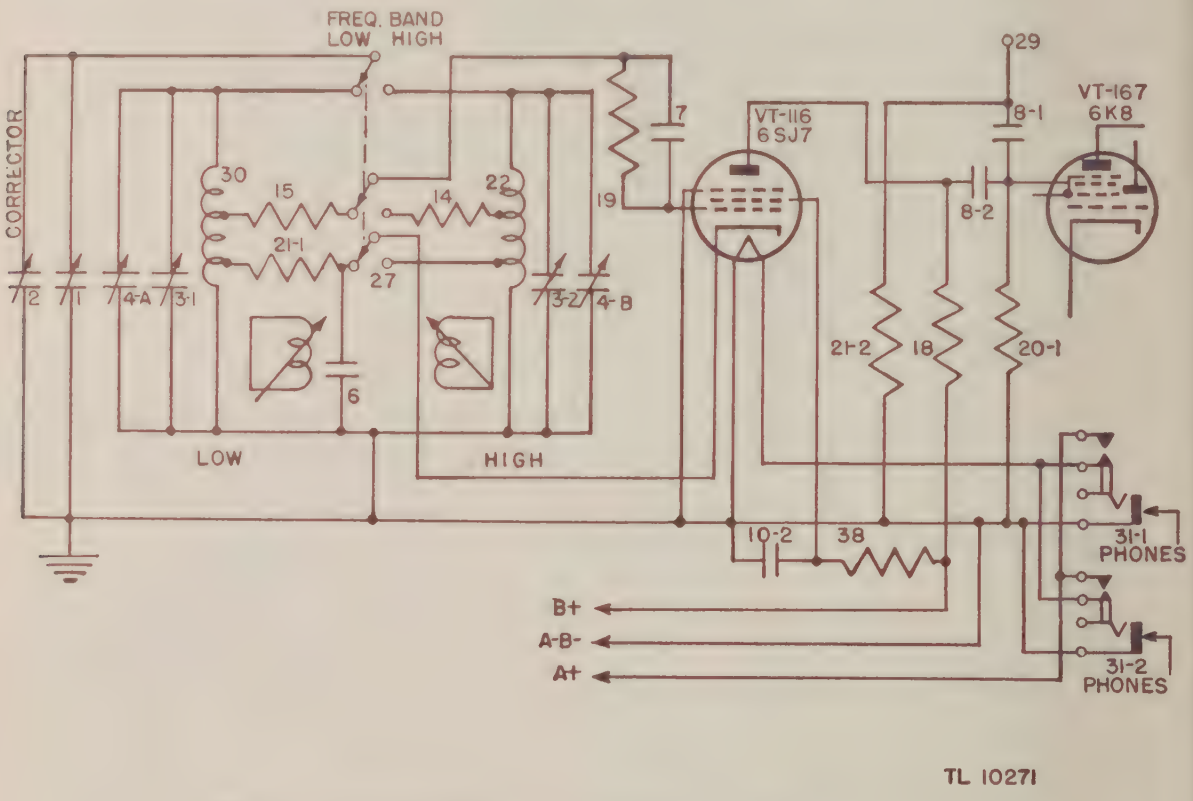


Figure 69. Frequency Meter BC–221–(5), functional diagram, variable frequency oscillator circuit.

b. Band Selector Switch. Switch 27 is a double-throw, triple-pole switch with all contacts mounted on ceramic plates. In order to minimize abnormal capacitive effects, all contacts are made as small as possible and are of the self-aligning,

self-wiping type. The switch has a heavy detent which accurately locates the rotor plate in either one of its two positions.

c. Corrector Control. Capacitor 2, the CORRECTOR control, with a range of 1.5 micromicrofarads (1.5muf), enables the operator to control the variable capacitance of the tuned circuit in order to compensate for slight changes in the circuit. (See par. 94f.)

d. Trimming Capacitors. The trimming capacitors are parts 3–1 and 3–2. The associated thermal compensator capacitors, part Nos. 4–A and 4–B, reduce changes in circuit capacitance due to temperature changes. Since the coils are compensated for changes in inductance, *a* above, frequency drifts due to temperature changes are negligible. The trimming capacitors are adjusted at the factory to build up the fixed capacitance of the LOW and HIGH frequency circuits to the exact values called for by the design of the variable tuning capacitor.

Caution: Do not tamper with these trimmer capacitor settings. To do so will throw the meter completely off calibration.

e. Oscillator Function. (1) The variable frequency oscillator circuit is in operation at the CHECK and OPERATE positions of operation switch 28. (See fig. 71.)

(2) At the CHECK position, the output of oscillator Tube VT-116 (6SJ7) is applied to one of the grids of detector-converter Tube VT-167 (6K8), where it is mixed with the output frequency of the crystal circuit. The result is a frequency equal to the difference of the two and is used to adjust the frequency of the oscillator by means of the CORRECTOR control.

(3) At the OPERATE position, the variable frequency oscillator is in operation, while the crystal oscillator is not. If the antenna is in position, the frequency meter may be used to receive or send any frequency in its range; that is, it may be used as a radio receiver or transmitter.

204. Detector Tube Circuit

It has been stated that the triode section of Tube VT–167 (6K8) is used in the crystal-oscillator circuit. The remaining hexode section of the tube of which the No. 1 grid is tied to the control grid of the triode section, is used as a high gain screen grid detector with hexode grid No. 3 acting as the control grid. The joint action of grids Nos. 1 and 3 produces electron coupling of the signals on the two grids. (See fig. 70.) Resistor 20–1 is the detector tube grid leak. Resistor 16 supplies voltage to the screen grid of Tube VT–167 (6K8). Capacitor 13 bypasses the screen grid to the cathode of the tube. Antenna plug 29 (part 33 in the BC–221–AA) is connected to ground through resistor 21–2. The r-f voltage, developed across load resistor 18 in the plate output circuit of the variable frequency oscillator, is coupled to the No. 3 grid of this detector through a small fixed capacitor 8–2. Antenna plug 29 (part 33 in the BC–221–AA) is also coupled to the No. 3 grid through coupling capacitor 8–1. As a result of these couplings to the control grid, the detector mixes the variable frequency oscillator output with the fundamental and successive harmonics of the crystal oscillator, when operation switch 28 is in the CHECK position, and with the radio transmitter frequency to be measured, when the switch is in the OPERATE position. By reference to figures 69 and 70 it can be seen that antenna plug 29 (part 33 in the BC–221–AA) is also coupled to the variable frequency oscillator output through capacitors 8–1 and 8–2 in series. Thus, the antenna connection serves the dual purpose of a detector input terminal for the measurement of frequencies of external origin and of a variable frequency oscillator output terminal for use in calibrating receivers. When the unit is employed for the latter purpose, a minimum of 2,000 microvolts of radio frequency energy will be available between the antenna terminal and ground (the chassis) at any frequency within the calibrated range.

205. Audio-Amplifying Circuit (par. 25).

The detector plate works into an audio-frequency choke coil 24, which is bypassed by capacitor 9 to reduce the response to high frequencies. The beat frequency voltages built up across the choke coil are coupled through capacitor 11 and GAIN control potentiometer 26 to the grid of Tube VT–116 (6SJ7) connected as a triode. The grid of Tube VT–116 returns to ground through potentiometer 26, and the necessary grid bias voltage is obtained by means of cathode dropping resistor 40. The plate (tied to the suppressor and screen grids) of Tube VT–116 returns to the positive plate supply voltage through plate load resistor 17. The plate of this tube is coupled also to PHONES jacks 31–1 and 31–2 through capacitor 12, so that no d-c voltage will be present in the output circuit. The characteristics of the output circuit are such that either high-impedance (15,000 ohms) or low-impedance (2,500 ohms) headsets may be used without any change-over adjustment being necessary.

206. Power Supply Circuit (fig. 71)

All power required for the operation of the meter is introduced through battery terminal board 36, located at the end of the battery cable. The common negative filament and negative plate battery leads are connected to the middle terminal which is grounded to the chassis. A fabricated wiring harness, or a fiber terminal board used in connection with a battery harness, is provided for intercell and filament battery to terminal board connections. Operation switch 28 closes both the positive 6-volt supply (A+) and the positive 135-volt supply (B+). The positive 6-volt supply (A+) is closed to the vacuum tube filaments through the auxiliary switches on PHONES jacks 31–1 and 31–2 when a headset plug is inserted in one of the jacks. Since the door covering the control panel cannot be closed with the headset plug in place, the *A* and *B* batteries cannot be discharged even though the operation switch is left in an active position when the meter is removed from service.

Section IV. MAINTENANCE

207. General

For all details of field maintenance, see paragraphs 26, 27, and 28.

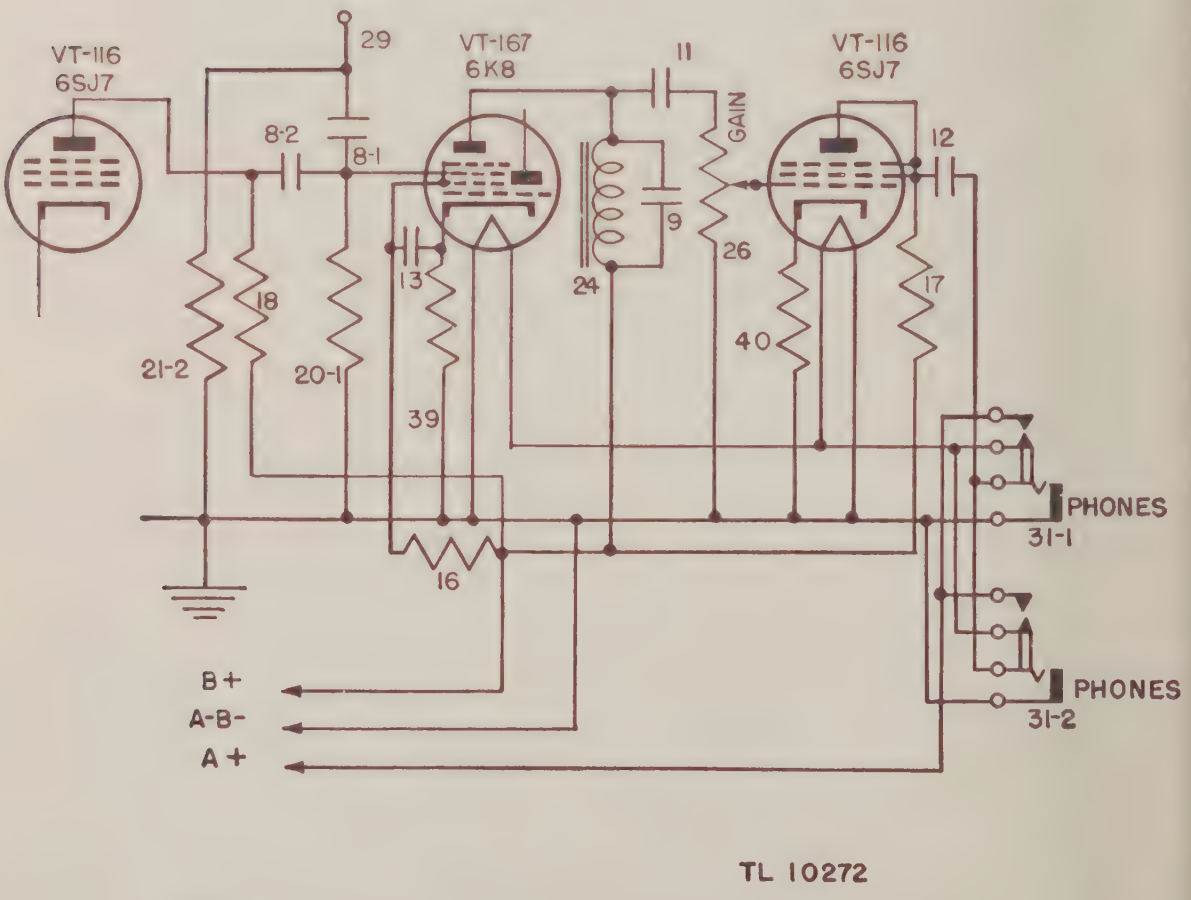


Figure 70. Frequency Meter BC–221–(5), functional diagram, detector and audio-amplifier circuits.

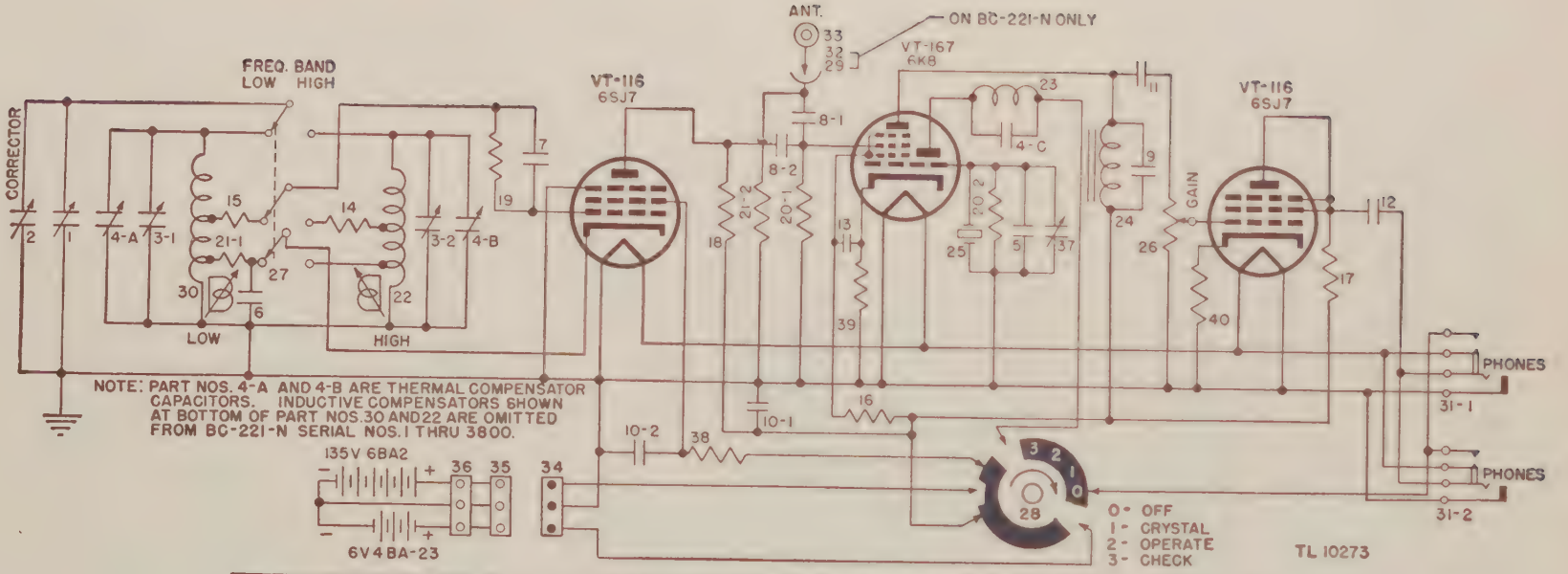
Section V. SUPPLEMENTARY DATA

208. Tabular List of Maintenance Parts for Frequency Meters BC–221–N and BC–221–AA

NOTE. Order maintenance parts by stock number, name, and description.

Ref. No. symbol	Signal Corps stock No.	Name of part and description	Quan. per equip.	Lowest maint. echelon
	2Z481N	BAG: BG–81–N; carrying	1*	3d
	2Z481AA	BAG: BG–81–AA; carrying	1*	3d
	2Z5531–160	BAG: BG–160–(&)/S; available for amphibious operations	1	Orgn stock
	3A2	BATTERY: BA2; 22.5=v	6	3d
	3A23	BATTERY: BA23; 1.5=v	4	3d
	3E1605–0.5	CORD: CD–605; 6½=ft.; 2=cond.; PL–55 at one end; Transformer C-410 at other	1	3d
	3L1874	CORD: CD–874; 6½=ft.; 2=cond.; PL–55 at one end; JB–47 on other end	1	3d
	2B830(&)	HEADSET: HS–30–(&); component HEADSET: HS–30–(&); repair parts	1	Orgn stock
	2B1300	INSERT: M–300	2	Orgn stock
	2Z9019A	STRAP: ST–19–A	1	3d

* Only one Bag BG–81–N or BG–81–AA is furnished per equipment.



REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	200 μμf	9	.002 μf	17	15,000 OHM	25	CRYSTAL	35	POWER JACKS
2	1.2 μμf	10–1&2	.1 μf	18	50,000 OHM	26	0.5 MEGOHM	36	BATTERY TERM.
3–1&2	15 μμf	11	.25 μf	19	330,000 OHM	27	SWITCH	37	12 μμf
4–A,B,C	10 μμf	12	2 μf	20–1&2	1 MEGOHM	28	SWITCH	38	20,000 OHM
5	6.5 μμf**	13	.001 μf	21–1&2	5,000 OHM	30	7.06 MILLIHY	39	150 OHM
6	250 μμf	14	27 OHM*	22	25.84 MICROHY	31–1&2	JACK	40	350 OHM
7	15 μμf	15	1,500 OHM	23	735 MICROHY	33	BINDING POST		
8–1&2	25 μμf	16	10,000 OHM	24	40 HENRYS *	34	POWER PLUGS		

*ON BC-221-N
REF. ITEM 14 IS 25 OHM.
REF. ITEM 24 IS 50 HENRIES.
REF. ITEM 29 IS ANT. PLUG.
REF. ITEM 32 & 33 BINDING POST
*ON EARLY MODEL BC-221-N
REF. ITEM 5 IS 8.5 μμf.

Figure 71. Frequency Meters BC–221–N and BC–221–AA, schematic diagram.

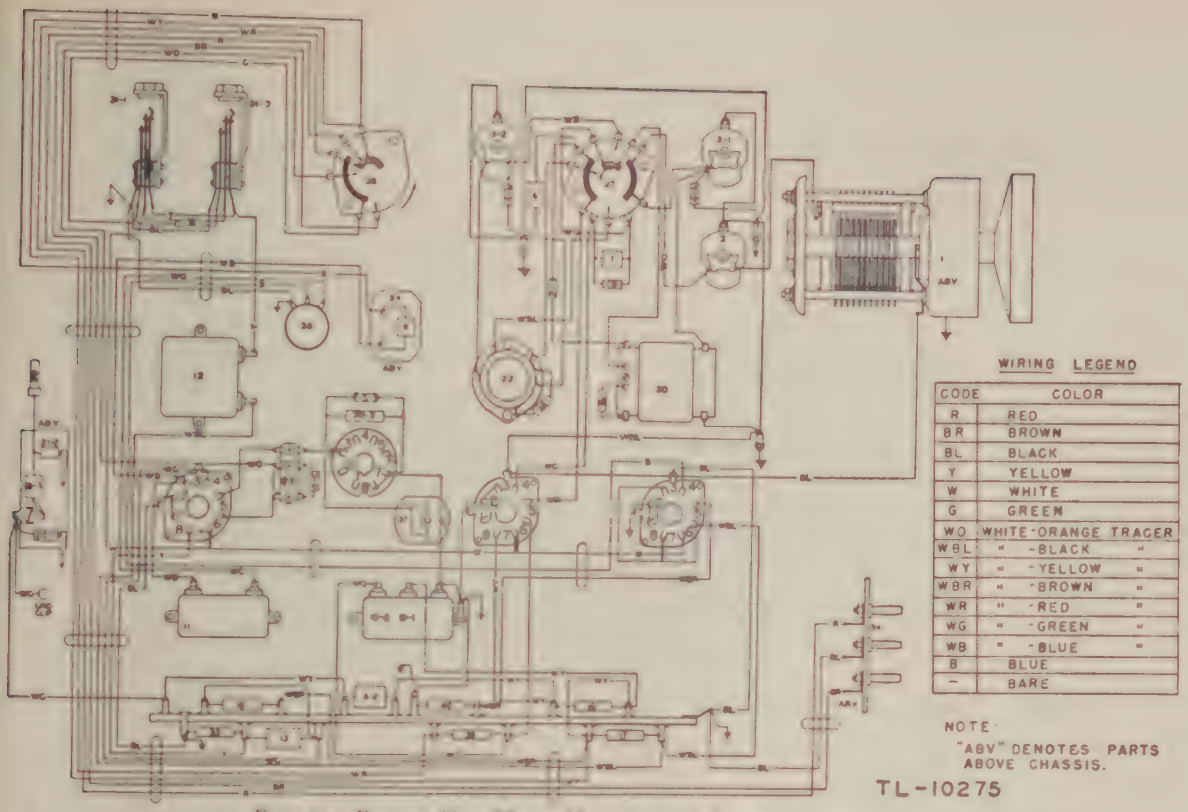


Figure 72. Frequency Meter BC-221-N, chassis wiring diagram.

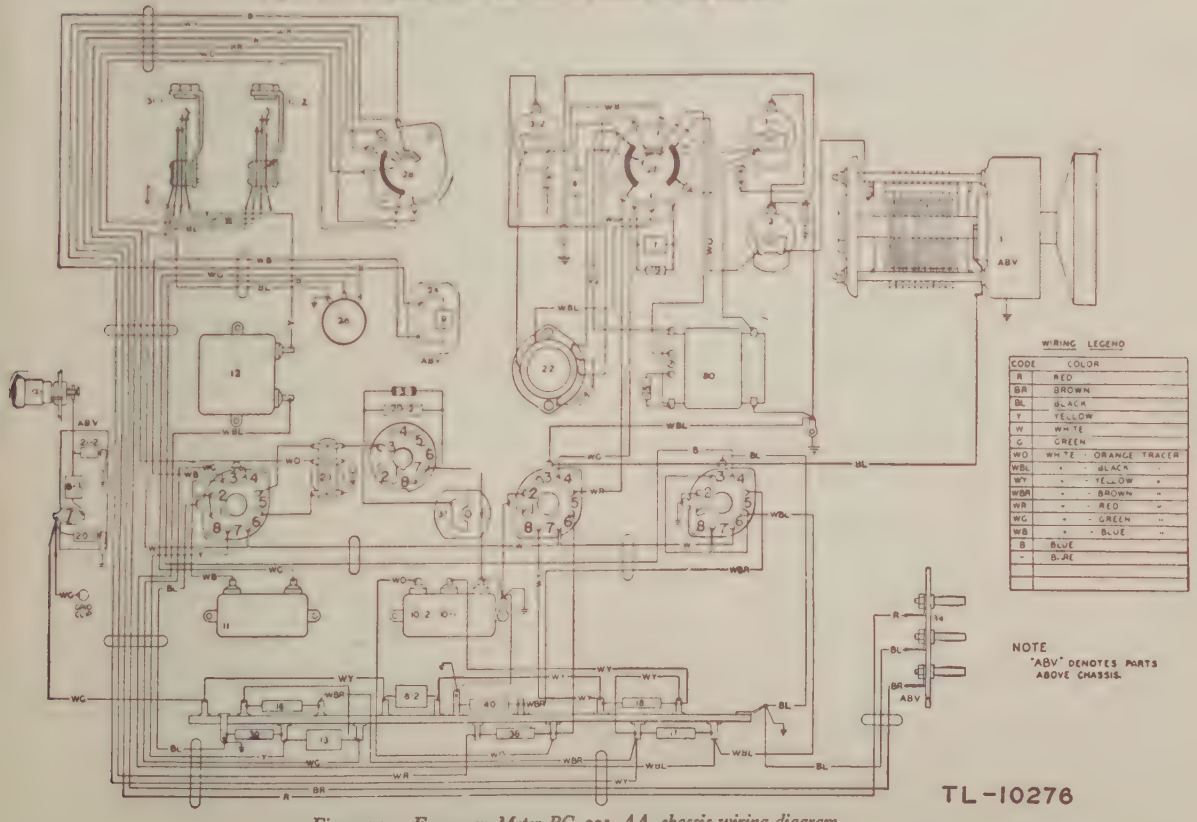


Figure 73. Frequency Meter BC-221-AA, chassis wiring diagram.

CHAPTER 8

FREQUENCY METER SETS SCR–211–P, SCR–211–T, SCR–211–AF, AND SCR–211–AH

Section I. DESCRIPTION

209. General

Frequency Meter Sets SCR–211–P, SCR–211–T, SCR–211–AF, and SCR–211–AH have been manufactured by the Zenith Radio Corporation on several orders. Sets SCR–211–P, and SCR–211–T are exactly alike in all electrical and mechanical details. Nomenclature and order numbers differ, however. The SCR–211–AF and the SCR–211–AH are very similar to these two models and to each other, but vary in arrangement of the variable frequency oscillator circuit and in part sizes and designations. These differences are discussed in detail in applicable parts of this chapter. For further general information see paragraph 2. The symbol (6) as used in this chapter refers to either the SCR–211–P, SCR–211–T, SCR–211–AF, or SCR–211–AH.

210. Components

Each Frequency Meter Set SCR–211–(6) includes the following component units:

Quantity	Component
1	Frequency Meter BC–221–(6) includes:
	1 Crystal Unit DC–9–P or DC–9–T (in operating position)[1].
	1 Calibration Book MC–177–(6).
	1 Wrench for Bristo No. 8 setscrew (spares compartment).
2	Tube VT–116–B, type 6SJ7Y (one in use, one spare).
2	Tube VT–116, type 6SJ7 (one in use, one spare)[2].
2	Tube VT–167, type 6K8 (one in use, one spare).
1	Strap ST–19–A.
2	Technical manuals or preliminary instruction books for Frequency Meter Set SCR–211–(6).
1	Cord CD–874[3] for Headset HS–30–(&).
1	Bag BG–81–(6)[4].

[1] Any crystal unit with nomenclature N or higher can be used interchangeably with any frequency meter set with nomenclature N or higher.

[2] This item is sometimes replaced with two Tubes VT–116–B in Frequency Meter Sets SCR–211–P and SCR–211–T.

[3] This item is not furnished with the SCR–211–P or SCR–211–T.

[4] A bag is not furnished with the SCR–211–AF or SCR–211–AH. A suitable canvas cover is supplied with the wooden cabinet and is not considered to be a separate component.

211. Additional Equipment Required

The following equipment not furnished with the orders is required to complete each Frequency Meter Set SCR–211–(6):

Quantity	Article
1.....	Headset P–18 or P–20[1].
1.....	Headset HS–30 (&)[2].
6.....	Batteries BA–2.
4.....	Batteries BA–23.

[1] Not used with the SCR 211-AF and SCR 211-AH.
[2] For use with the SCR 211-AF and SCR 211-AH.

212. Total Weight

Frequency Meter Set SCR–211–(6), complete and ready for service, weighs as follows: SCR–211–P, 38.8 pounds; SCR–211–T, 42.3 pounds; SCR–211–AF, 39.5 pounds; and SCR–211–AH, 39.5 pounds. For typical dimensions, see figures 26 and 27.

213. Power Consumption

All power required for the operation of this equipment is supplied by the batteries listed in paragraph 211. The current drains at the specified voltage limits are as follows:

Filaments: 5.4 to 6.0 volts, 0.86 to 0.92 ampere.

Plates, etc.: 121.5 to 135.0 volts, 0.015 to 0.17 ampere.

These values are typical for operation with the operation switch at the XTAL CHECK position, under which condition maximum plate current is drawn.

214. Controls (pars. 2e and 154)

215. Vacuum Tubes

The vacuum tubes used in the Frequency Meter Set SCR–211–(6) are shown in the following tabulation:

Section II.

INSTALLATION AND OPERATION

216. Initial Procedure (par. 7)

Make sure a spare set of vacuum tubes is installed in the space provided.

217. Installation of Batteries

See paragraph 8; then proceed as follows:

a. For Frequency Meter BC–221–P and BC–221–T, proceed as directed in paragraph 38.

b. For the BC–221–AF and BC–221–AH, proceed as directed in paragraph 187b.

218. Antenna (par. 9)

219. Headset (par. 10)

A headset plug must be inserted in one of the PHONES jacks before the meter will operate.

220. Preparation for Use (par. 160)

221. Reading the Dial (par. 11)

222. Calibration Book MC–177–(6) (par. 12)

223. Operating Circuits (par. 13)

224. Zero Beat Detection (par. 14)

225. Correction in Calibration (par. 165)

226. Crystal Check Points (par. 16)

227. Frequency Measurements (par. 17)

The proper position of the operation switch of the BC–221–(6) is HET. OSC. for making frequency measurements as described in paragraph 17.

228. Precautions During Operation (par. 18)

229. Adjustments for Field Upkeep (par. 19)

Reference	Function	Signal Corps type nomenclature	Commercial equivalent	Base
VT–116–B	Variable frequency oscillator.	VT–116–B	6SJ7Y.....	Octal
VT–167.....	Crystal oscillator and detector.	VT–167.....	6K8.....	Octal
VT–116g.....	Audio-frequency amplifier	VT–116*.....	6SJ7.....	Octal

* Tubes VT–116–B are sometimes substituted for Tubes VT–116 in the SCR–211–P and SCR–211–T.

NOTE. Tube VT–116–B is practically the same as Tube VT–116, but has a special electrically low-loss base. In an emergency, a VT–116 can be used in the variable frequency oscillator, but temperature and humidity changes might cause undesirable effects.

Section III. FUNCTIONING OF PARTS

230. General

Frequency Meter BC–221–(6) is very similar to the meters described in chapter 6 of this manual. The BC–221–P and BC–221–T are exactly alike and are treated as such in this section. The BC–221–AF and the BC–221–AH are very similar to these two models and to each other, but vary in the variable frequency oscillator circuits as well as in part sizes and designations. These variations are covered by separate diagrams of the operating circuits and such additional explanatory remarks as may be required.

231. Circuit Components (par. 21)

The oscillator circuit is designed to generate considerable harmonic energy so that it can be used to calibrate the variable frequency oscillator at several points over its entire range, as well as to supply whole multiples of 1,000 kc for the calibration of receivers and similar equipment. The necessary plate circuit impedance is built up across an untuned inductance 18, which is thoroughly sealed against moisture. Resistor 23–1 is the oscillator grid leak and works in conjunction with the tube cathode resistor 7 to furnish bias for proper oscillator operation. The r-f choke 24 in the cathode lead (not installed in the BC–221–AH) serves to increase the response of the detector circuit at harmonics of the crystal frequency; that is, at CRYSTAL

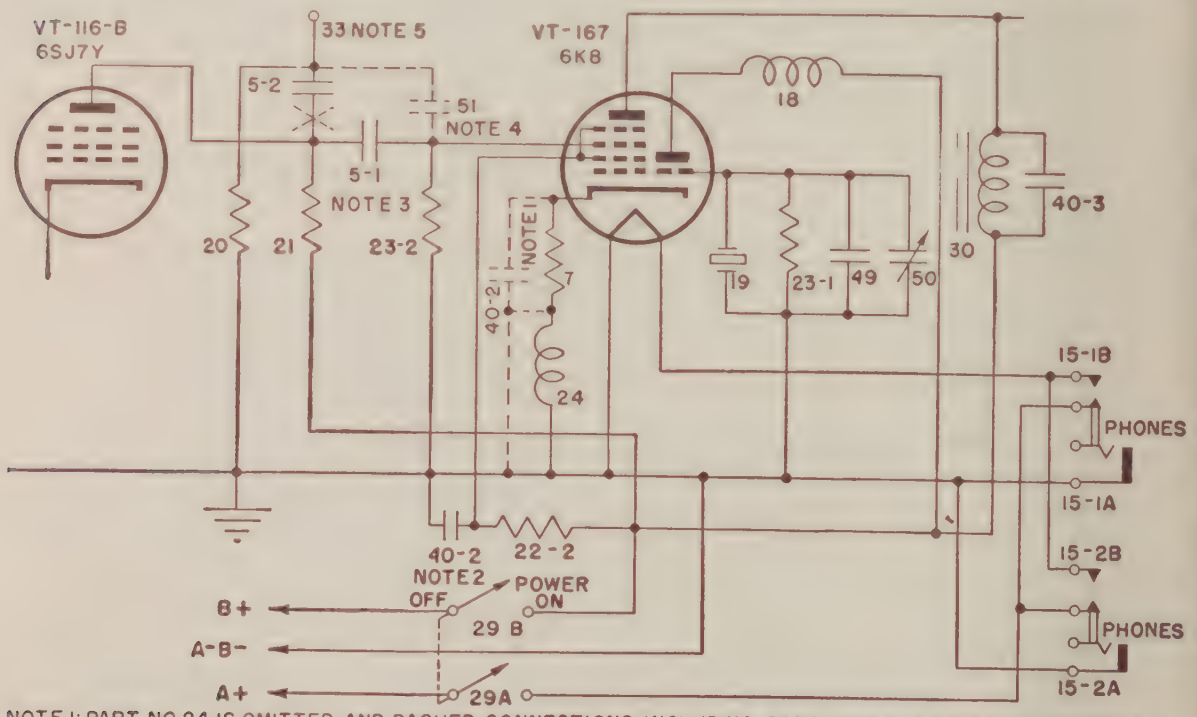


Figure 74. Frequency Meter BC–221–(6), functional diagram, crystal-oscillator circuit.

232. Crystal Circuit

The crystal circuit uses the triode section of Tube VT–167 (6K8). (See fig. 74.) The oscillator operates at the fixed frequency of 1,000 kc when the operation switch 28 is placed in the XTAL CHECK or XTAL ONLY position. The operation switch controls the crystal oscillator by opening or closing its plate voltage circuit. CHECK POINTS. The variable capacitor 50 is connected across the crystal 19 for the purpose of adjusting the frequency of the crystal to a closer point than can be economically obtained by grinding alone. When the frequency meters are adjusted during manufacture, the variable capacitor is set up to produce a frequency of 1,000 kc ± 5 cycles at 20° centigrade. The fixed

capacitor 49, shunted across the crystal, minimizes any change in fundamental frequency due to small changes in the crystal capacitance. Further reference to figure 74 shows that the output of the crystal oscillator is electron coupled to the antenna through the No. 3 grid of the hexode section of Tube VT–167 and capacitors 5–1 and 5–2 in series (through capacitor 51 only in the BC–221–AH). For further details on the crystal oscillator, see paragraph 22.

233. Variable Frequency Oscillator Circuit (par. 23)

Tube VT–116–B (6SJ7Y) is used in an electron coupled circuit as the variable frequency oscillator. (See figs. 75 and 76.)

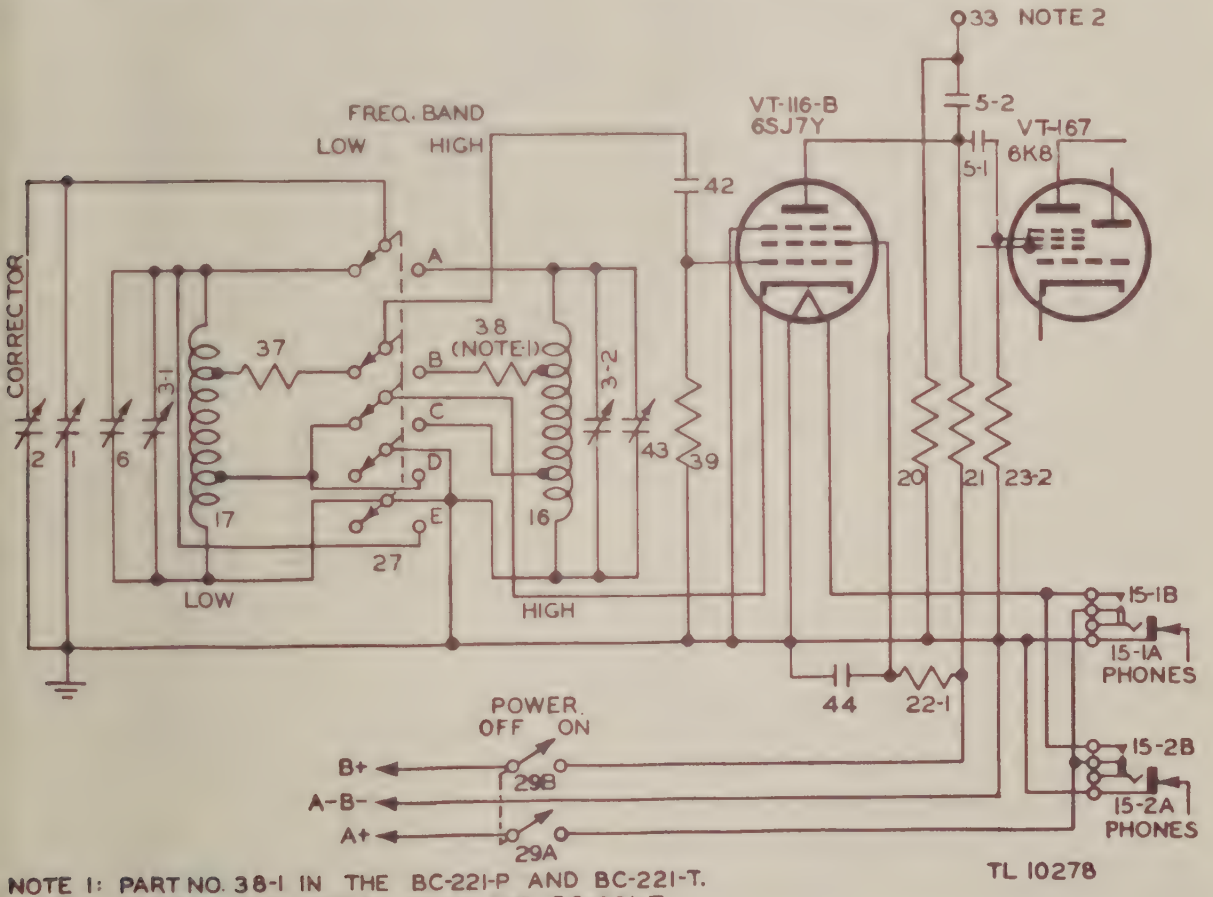


Figure 75. Frequency Meters BC–221–P, BC–221–T, and BC–221–AF, functional diagram, variable frequency oscillator circuit.

a. Coils. The two inductors 16 and 17, in the tuned circuits are wound on ceramic forms and thoroughly sealed against moisture to eliminate the influence of changing atmospheric conditions on the stability of the meter. The active terminals of these coils are connected across the terminals of the main tuning capacitor 1 by means of the band selector (FREQ. BAND LOW-HIGH) switch 27. Each coil and the tuning capacitor, together with other capacitors mentioned below constitute the resonant circuit that determines the output frequency. The correct operating bias on the control grid of the oscillator tube is provided by the grid-leak resistor 39. (Note the different connections of the grid-leak resistor employed. In the BC–221–P, BC–221–T, and BC–221–AF the grid leak is connected between grid and ground, and capacitor 42 couples the grid to taps on the tuned circuits through the band selector switch. In the BC–221–AH, the grid leak is parallel with capacitor 42, is connected in the coupling lead from the grid to the band selector switch. The operation of both methods of connection is the same.) The frequency of oscillation is made independent of variations in tube characteristics when the grid connection is tapped down an appreciable distance from the high-potential end

of the coil. The resistors 37 and 38 (38–1 in the BC–221–P and BC–221–T), which carry little current, are connected in series with the grid circuit taps on the coils and serve to stabilize the operation of the oscillator circuit by suppressing undesirable oscillations. The second coil tap, located near the grounded end of each coil and connected to the cathode of the oscillator tube through another set of contacts on switch 27, controls the amount of feedback in the oscillator circuit. In the BC–221–AH only, resistor 24 in this lead to the LOW frequency sistor 21 is the oscillator tube plate circuit load, and the voltage developed across it is coupled to detector-converter Tube VT–167 through capacitor 5–1 (capacitor 5 in the BC–221–AH) or to the antenna through capacitor 5–2 (capacitors 5 and 51, in series, in the BC–221–AH). Resistor 22–1 is the screen grid dropping resistor, and part 44 (part 9–2 in the BC–221–AH) is the screen grid bypass capacitor to ground.

b. Band Selector Switch. (1) In the BC–221–P, BC–221–T, and BC–221–AF, the band selector switch is a double throw, five-pole

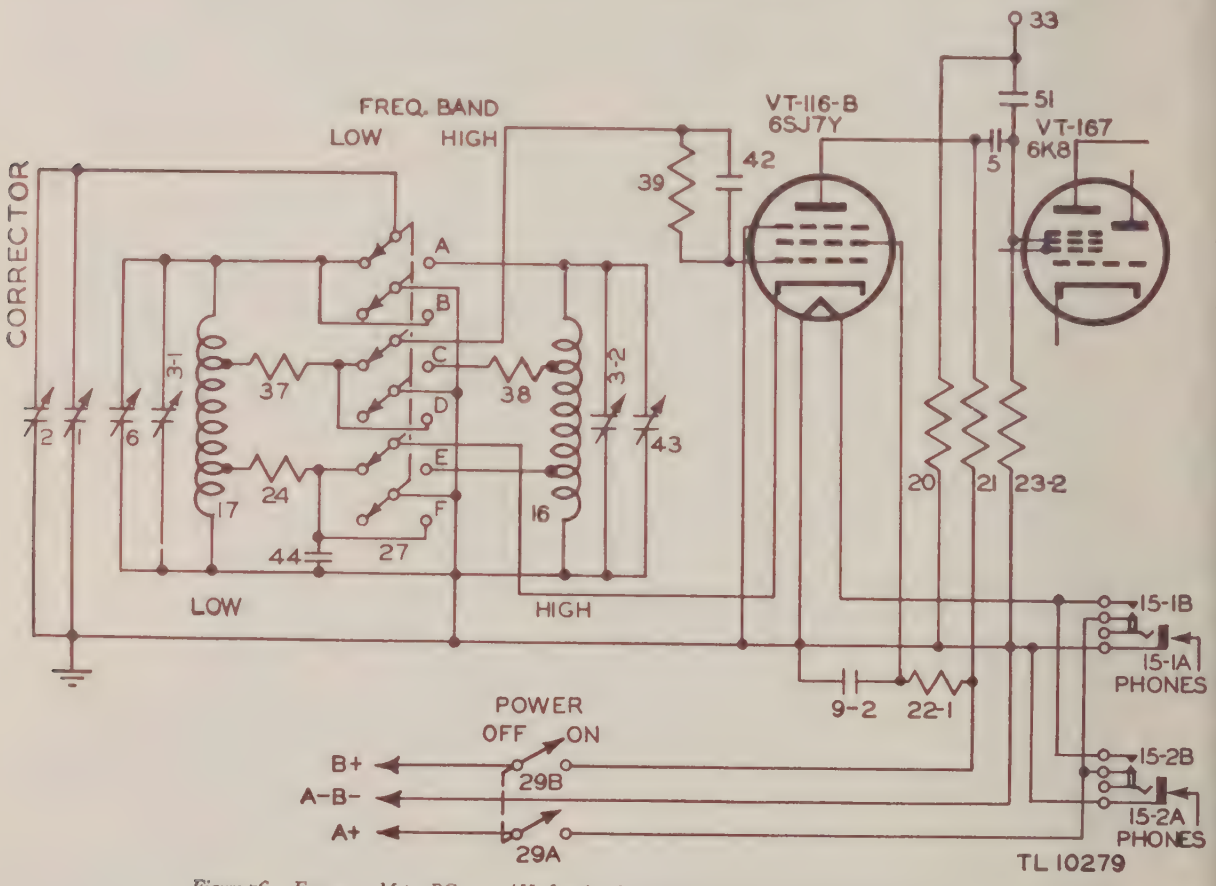


Figure 76. Frequency Meter BC–221–AH, functional diagram, variable frequency oscillator circuit.

coil develops additional cathode bias voltage when the band selector switch is in the LOW position. Capacitor 44 bypasses this resistor to ground. Note that in the case of the BC–221–P, BC–221–T, and BC–221–AF, section *e* of switch 27 shorts out all of coil 17 when the switch is in the HIGH position. In the case of the BC–221–AH, sections *b*, *d*, and *f* of switch 27 ground coil 17 at three different points when the switch is in the HIGH position. These circuit arrangements prevent interaction between the two coils when the switch is in the HIGH position. Re-

switch. (See fig. 75.)

(2) In the BC–221–AH, the band selector switch 27 is a double-throw, six-pole switch. (See fig. 76.)

(3) All contacts of these switches are mounted on ceramic plates. In order to minimize abnormal capacitive effects, all contacts are made as small as possible and are of the self-aligning, self-wiping type. Each switch has a heavy detent, which accurately locates the rotor plate in either one of its two positions.

c. CORRECTOR Control. Capacitor 2, the

CORRECTOR control, with a range of 3 microfarads (3$\mu\mu$f), enables the operator to control the variable capacitance of the tuned circuit in order to compensate for slight changes in the circuit. (See par. 154g.)

d. Trimming Capacitors. The trimming capacitors are parts 3–1 and 3–2. These are equipped with thermal compensator capacitors part Nos. 6 and 43, which prevent frequency drifts due to temperature changes. Note that in the BC–221–P, BC–221–T, and BC–221–AF trimming capacitor 3–1 and capacitor 6 are short-circuited to ground by section *e* of operation switch 27 in the HIGH position. The same operation is performed by section *b* on switch 27 in the BC–221–AH. This is a means of reducing interaction between the two coils in the oscillator circuit. The trimming capacitors are adjusted at the factory to build up the fixed capacitance of the LOW and HIGH frequency circuits to the exact values called for by the design of the variable tuning capacitor.

Caution: Do not tamper with these trimmer capacitor settings. To do so will throw the meter completely off calibration.

e. Oscillator Function. (1) The variable frequency oscillator is in operation whenever the POWER switch 29 is in the ON position, the operation switch 28 is in either the HET. OSC. or XTAL CHECK position, and a headset is plugged into a PHONES jack.

(2) At the XTAL CHECK position of the operation switch 28, the output of oscillator Tube VT–116–B is applied to the No. 3 grid of the hexode section of Tube VT–167 where it is mixed with the output frequency of the crystal circuit. The result is a frequency equal to the difference of the two and is used to adjust the frequency of the oscillator with the CORRECTOR control.

(3) At the HET. OSC. position of the operation switch 28, the variable frequency oscillator is in operation, while the crystal oscillator is not. If the antenna is in position, the frequency meter may be used to receive or send any frequency in its range; that is, it may be used as a radio receiver or transmitter.

234. Detector Tube Circuit

It has been stated that the triode section of Tube VT–167 (6K8) is used in the crystal-oscillator circuit. The remaining hexode section of the tube, of which the No. 1 grid is tied to the control grid of the triode section, is used as a high gain screen grid detector with hexode grid No. 3 acting as the control grid. The joint action of grids Nos. 1 and 3 produces electron coupling of the signals on the two grids. (See fig. 77.) Resistor 23–2 is the detector tube grid leak. Resistor 22–2 supplies voltage to the screen grid of Tube VT–167 (6K8). Capacitor 40–2 (part No. 45–1 in the BC–221–AH) bypasses the screen grid to ground. Note that the antenna plug 33 (part No. 31 in the BC–221–P and BC–221–T) is connected to ground through the resistor 20. The r-f voltage, developed across the load resistor 21 in the plate output circuit of the variable frequency oscillator, is couple to the No. 3 grid of this detector through a small fixed capacitor 5–1 (capacitor 5 in the BC–221–AH). The antenna plug 33 (31 for the BC–221–P and BC–221–T) is also coupled to the No. 3 grid through the coupling capacitors 5–2 and 5–1 in series (through capacitor 51 alone in the BC–221–AH). As a result of these couplings to the control grid, the detector mixes the variable frequency oscillator output with the fundamental and successive harmonics of the crystal oscillator when the operation switch 28 is in the XTAL CHECK position and with the radio transmitter frequency to be measured when the switch is in the HET. OSC. position. By reference to figures 75, 76, and 77 it can be seen that the antenna plug 33 (part 31 in the BC–221–P and BC–221–T) is also coupled to the variable frequency oscillator output through capacitor 5–2 (through capacitors 51 and 5, in series, in the BC–221–AH). Thus, the antenna connection serves the dual purpose of a detector input terminal for the measurement of frequencies of external origin and of a variable frequency oscillator output terminal for use in calibrating receivers. When the unit is employed for the latter purpose, a minimum of 2,000 microvolts of radio frequency energy will be available between the antenna terminal and ground (the chassis) at any frequency within the calibrated range.

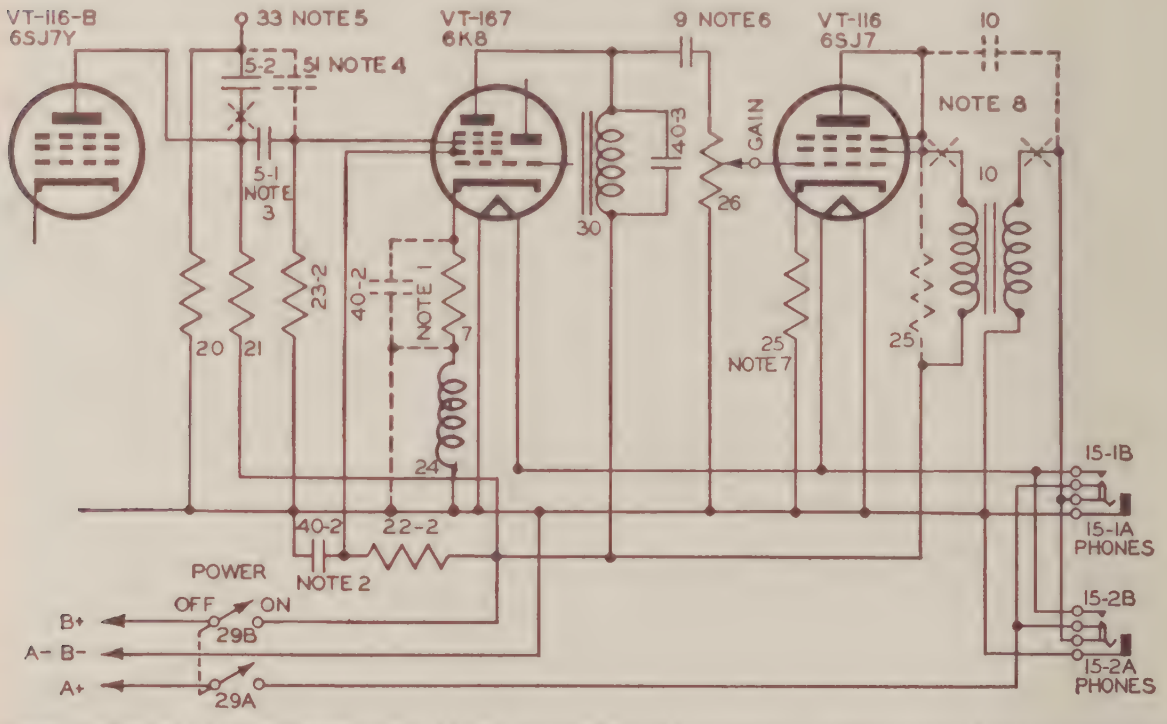
235. Audio-Amplifying Circuit (par. 25)

The detector plate works into an audio-frequency choke coil 30, which is bypassed by the capacitor 40–3 to reduce the response to high frequencies. The beat frequency voltages built up across the choke coil are coupled through capacitor 9 (capacitor 9–1 in the BC–221–AH) and the GAIN control potentiometer 26 to the grid of Tube VT–116 (6SJ7), connected as a triode. The grid of Tube VT–116 returns to ground through the potentiometer 26, and the necessary grid bias

voltage is obtained by means of the cathode dropping resistor 25 (resistor 38–2 in the BC–221–P and BC–221–T). The plate (tied to the suppressor and screen grids) of Tube VT–116 returns to the positive plate supply voltage through the plate load resistor 25 in the BC–221–P and BC–221–T, and through the primary of the audio-output transformer 10 in the BC–221–AF and BC–221–AH. In the BC–221–P and BC–221–T, the plate of this tube is coupled also to the PHONES jacks 15–1a and 15–2a through capacitor 10, so that no d-c voltage will be present in the output circuit. In the BC–221–AF and BC–221–AH, the same is accomplished by the audio-output transformer, the secondary of which is connected to the PHONES jacks and ground. The characteristics of the output circuit of the BC–221–P and BC–221–T are such that either high-impedance (15,000 ohms) or low-impedance (2,500 ohms) headsets may be used without any change-over adjustments being necessary. The output circuit of the BC–221–AF and BC–221–AH is designed for the use of the low impedance type Headset HS–30–(&). Under certain conditions, the high impedance type Headset P–18 or P–20 might be substituted for the HS–30–(&), but the results obtained will in general be inferior.

236. Power Supply Circuit (figs. 78, 79, and 80)

All power required for the operation of the meter is introduced through the battery terminal board 36, located at the end of the battery cable. The common negative filament and negative plate battery leads are connected to the middle terminal which is grounded to the chassis. A fabricated wiring harness is provided for inter-cell and filament battery to terminal board connections in Frequency Meters BC–221–P and BC–221–T. A fiber terminal board is provided, in addition, to the BC–221–AF and BC–221–AH



NOTE 1: PART NO. 24 IS OMITTED AND DASHED CONNECTIONS INCLUDING PART NO. 40-2 APPLY TO BC-221-AH
NOTE 2: PART NO. 45-1 IN THE BC-221-AH
NOTE 3: PART NO. 5 IN THE BC-221-AH
NOTE 4: CONNECTION SHOWN DASHED AND OPEN CIRCUIT SHOWN —✕— APPLIES TO BC-221-AH
NOTE 5: PART NO. 31 IN THE BC-221-P AND BC-221-T
NOTE 6: PART NO. 9-1 IN THE BC-221-AH
NOTE 7: PART NO. 38-2 IN THE BC-221-P AND BC-221-T
NOTE 8: CONNECTIONS SHOWN DASHED AND OPEN CIRCUITS SHOWN —✕— APPLY TO BC-221-P AND BC-221-T

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Figure 77. Frequency Meter BC–221–(6), functional diagram, detector and audio-amplifier circuits.

for connection of the *A* battery cells. Section 29*a* of the POWER switch closes the positive 6-volt supply terminal (A+) to the vacuum tube filaments through the auxiliary switches 15–1b and 15–2b on the PHONES jacks 15–1a and 15–2a when the headset plug is inserted in one of the jacks. Section 29*b* connects the positive 135-volt terminal (B+) to all plate and screen circuits. Since the door covering the control panel cannot be closed with the headset plug in place, the *A* and *B* batteries cannot be discharged even though the POWER switch is left in the ON position when the meter is removed from service.

Section IV. MAINTENANCE

237. General

For all details of field maintenance, see paragraphs 26, 27, and 28.

Section V. SUPPLEMENTARY DATA

238. Tabular List of Maintenance Parts

a. Frequency Meters BC–221–P and BC–221–T.

Note. Order maintenance parts by stock number, name, and description.

Ref. No. symbol	Signal Corps stock No.	Name of part and description	Quan. per equip.	Lowest maint. echelon
	2Z481P	BAG: BG–81–P; carrying	1*	3d
	2Z481T	BAG: BG–81–T; carrying	1*	3d
	2Z551–160	BAG: BG–160–(&)/S; available for amphibious operations	1	Orgn stock
	3A2	BATTERY: BA2; 22.5=v	6	3d
	3A23	BATTERY: BA23; 1.5=v	4	3d
	3E1605–6.5	CORD: CD–605; 6½=ft; 2=cond.; PL–55 at one end; Transformer C–410 at other	1	3d
	3E1874	CORD: CD–874; 6½=ft; 2=cond.; PL–55–at one end; JB–47 on other end	1	3d
	2B830(&)	HEADSET: HS–30–(&); component	1	Orgn stock
		HEADSET: HS–30–(&); repair parts		
	2B1300	INSERT: M–300	2	Orgn stock
	2Z9019A	STRAP: ST–19–A	1	3d

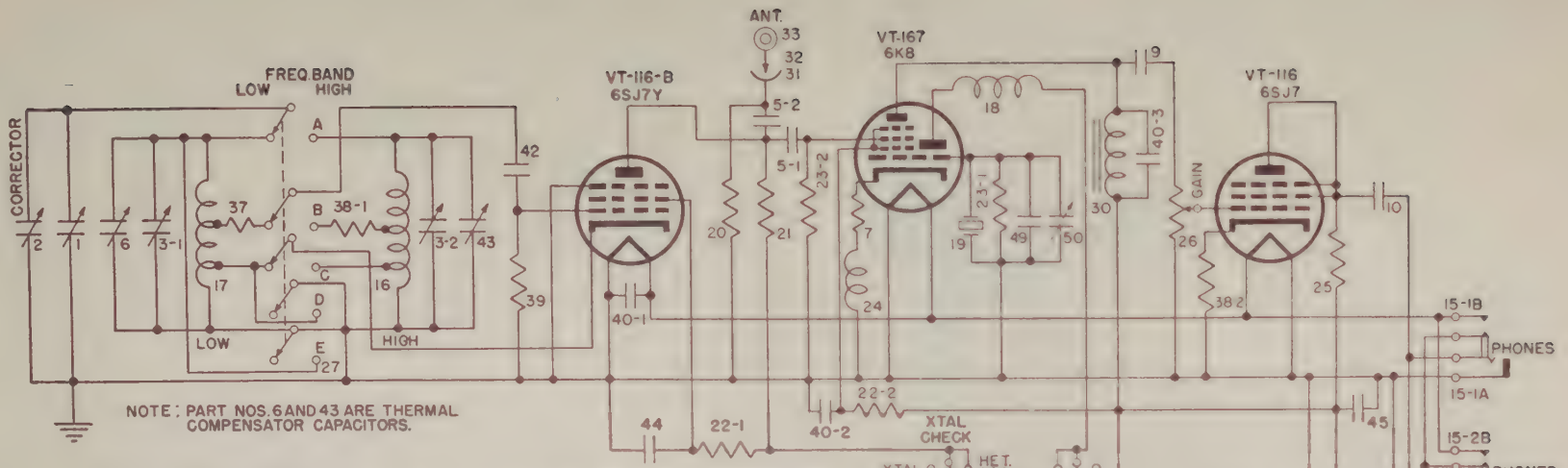
* Only one Bag BG–81–P or BG–81–T is furnished per equipment.

b. Frequency Meters BC–221–AF and BC–221–AH.

Note. Order maintenance parts by stock number, name, and description.

Ref. No. symbol	Signal Corps stock No.	Name of part and description	Quan. per equip.	Lowest maint. echelon
	2Z481AE	BAG: BG–81–AF; carrying	1*	3d
	2Z481AH	BAG: BG–81–AH; carrying	1*	3d
	2Z551–160	BAG: BG–160–(&) /S; available for amphibious operations	1	Orgn stock
	3A2	BATTERY: BA2; 22.5=v	6	3d
	3A23	BATTERY: BA23; 1.5=v	4	3d
	3E1605–6.5	CORD: CD–605; 6½=ft; 2=cond.; PL–55 at one end; Transformer C–410 at other	1	3d
	3E1874	CORD: CD–874; 6½=ft; 2=cond.; PL–55 on one end; JB–47 on other end	1	3d
	2B830(&)	HEADSET: HS–30–(&); component	1	Orgn stock
		HEADSET: HS–30–(&) repair parts		
	2B1300	INSERT: M–300	2	Orgn stock
	2Z9019A	STRAP: ST–19–A	1	3d

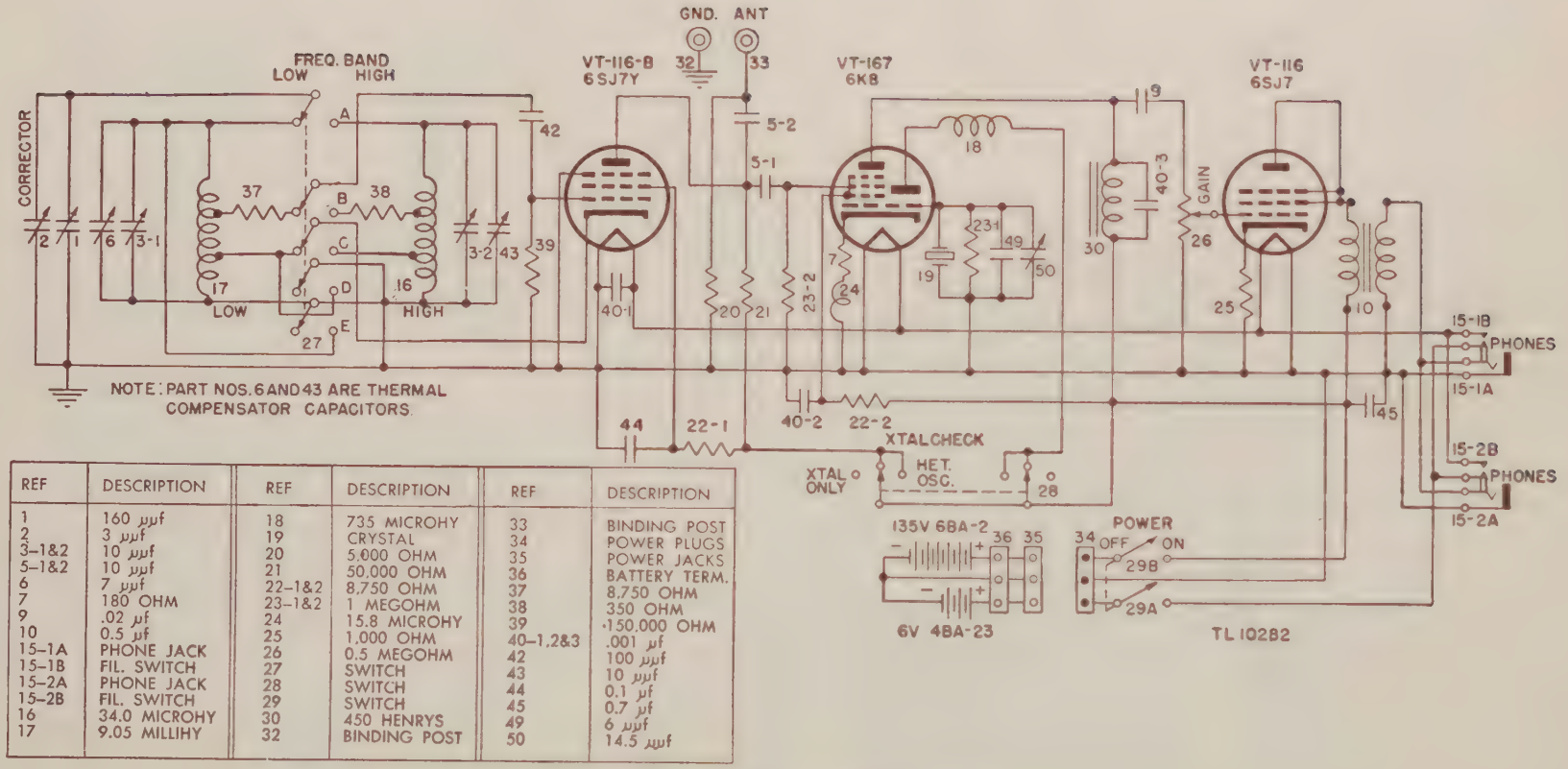
* Only one Bag BG-81-AF or BG-81-AH is furnished per equipment.



REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	160 μμf	19	CRYSTAL	34	POWER PLUGS
2	3 μμf	20	5,000 OHM	35	POWER JACKS
3–1&2	10 μμf	21	50,000 OHM	36	BATTERY TERM
5–1&2	10 μμf	22–1&2	8,750 OHM	* 37	4,500 OHM
6	7 μμf	23–1&2	1 MEGOHM	38–1&2	350 OHM
7	180 OHM	24	15.8 MICROHY	39	150,000 OHM
9	.02 μf	25	15,000 OHM	40–1,2&3	.001 μf
10	0.5 μf	26	0.5 MEGOHM	42	100 μμf
15–1A	PHONE JACK	27	SWITCH	43	10 μμf
15–1B	FIL. SWITCH	28	SWITCH	44	0.1 μf
15–2A	PHONE JACK	29	SWITCH	45	0.7 μf
15–2B	FIL. SWITCH	30	450 HENRYS	49	6 μμf
16	34.0 MICROHY	31	ANT. PLUG	50	14.5 μμf
17	9.05 MILLIHY	32	CONTACT SPRING		
18	735 MICROHY	33	BINDING POST		

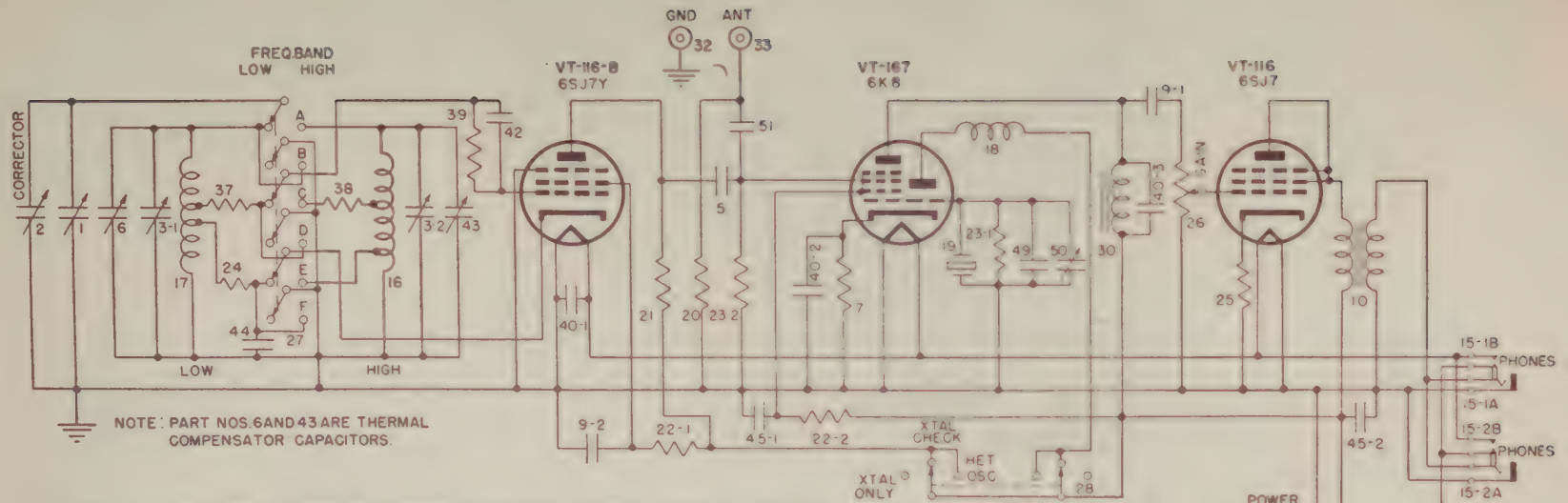
* NOTE: CHANGED TO 8750 OHM IN LATER MODEL BC-221-T

Figure 78. Frequency Meters BC–221–P and BC–221–T, schematic diagram.



REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	160 μμf	18	735 MICROHY	33	BINDING POST
2	3 μμf	19	CRYSTAL	34	POWER PLUGS
3–1&2	10 μμf	20	5,000 OHM	35	POWER JACKS
5–1&2	10 μμf	21	50,000 OHM	36	BATTERY TERM.
6	7 μμf	22–1&2	8,750 OHM	37	8,750 OHM
7	180 OHM	23–1&2	1 MEGOHM	38	350 OHM
9	.02 μf	24	15.8 MICROHY	39	150,000 OHM
10	0.5 μf	25	1,000 OHM	40–1,2&3	.001 μf
15–1A	PHONE JACK	26	0.5 MEGOHM	42	100 μμf
15–1B	FIL. SWITCH	27	SWITCH	43	10 μμf
15–2A	PHONE JACK	28	SWITCH	44	0.1 μf
15–2B	FIL. SWITCH	29	SWITCH	45	0.7 μf
16	34.0 MICROHY	30	450 HENRYS	49	6 μμf
17	9.05 MILLIHY	32	BINDING POST	50	14.5 μμf

Figure 79. Frequency Meter BC–221–AF, schematic diagram.



REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	160 μμf	15–2B	FIL. SWITCH	26	0.5 MEGOHM	38	100 OHM
2	3 μμf	16	35.0 MICROHY	27	SWITCH	39	150,000 OHM
3–1&2	10 μμf	17	9.2 MILLIHY	28	SWITCH	40–1, 2&3	.001 μf
5	10 μμf	18	1.0 MILLIHY	29	SWITCH	42	100 μμf
6	7 μμf	19	CRYSTAL	30	150 HENRYS	43	10 μμf
7	150 OHM	20	5,000 OHM	32	BINDING POST	44	50 μμf
9–1&2	.02 μf	21	50,000 OHM	33	BINDING POST	45–1&2	.25 μf
10	OUTPUT TRANS.	22–1&2	10,000 OHM	34	POWER PLUGS	49	6 μμf
15–1A	PHONE JACK	23–1&2	1 MEGOHM	35	POWER JACKS	50	12 μμf
15–1B	FIL. SWITCH	24	2,000 OHM	36	BATTERY TERM	51	25 μμf
15–2A	PHONE JACK	25	1,000 OHM	37	8,200 OHM		

Figure 80. Frequency Meter BC–221–AH, schematic diagram.

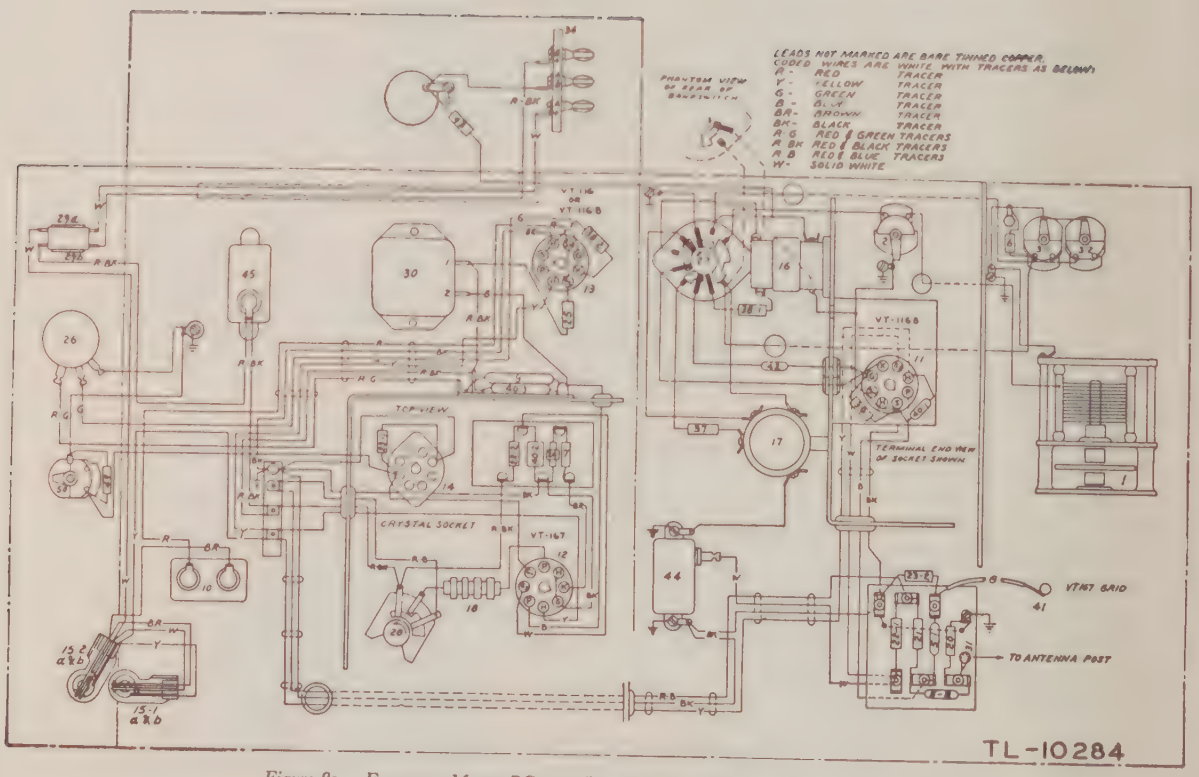

LEADS NOT MARKED ARE BARE TINNED COPPER.
CODED WIRES ARE WHITE WITH TRACERS AS BELOW:
R - RED TRACER
Y - YELLOW TRACER
G - GREEN TRACER
BR - BROWN TRACER
BK - BLACK TRACER
R G RED & GREEN TRACERS
R BK RED & BLACK TRACERS
R B RED & BLUE TRACERS
W - SOLID WHITE
PHANTOM VIEW OF REAR OF BAND SWITCH
VT-116 OR VT-116B
VT-116B
TOP VIEW
CRYSTAL SOCKET
VT-167
TERMINAL END VIEW OF SOCKET SHOWN
VT-167 GRID
TO ANTENNA POST
TL-10284

Figure 81. Frequency Meters BC-221-P and BC-221-T, chassis wiring diagram.

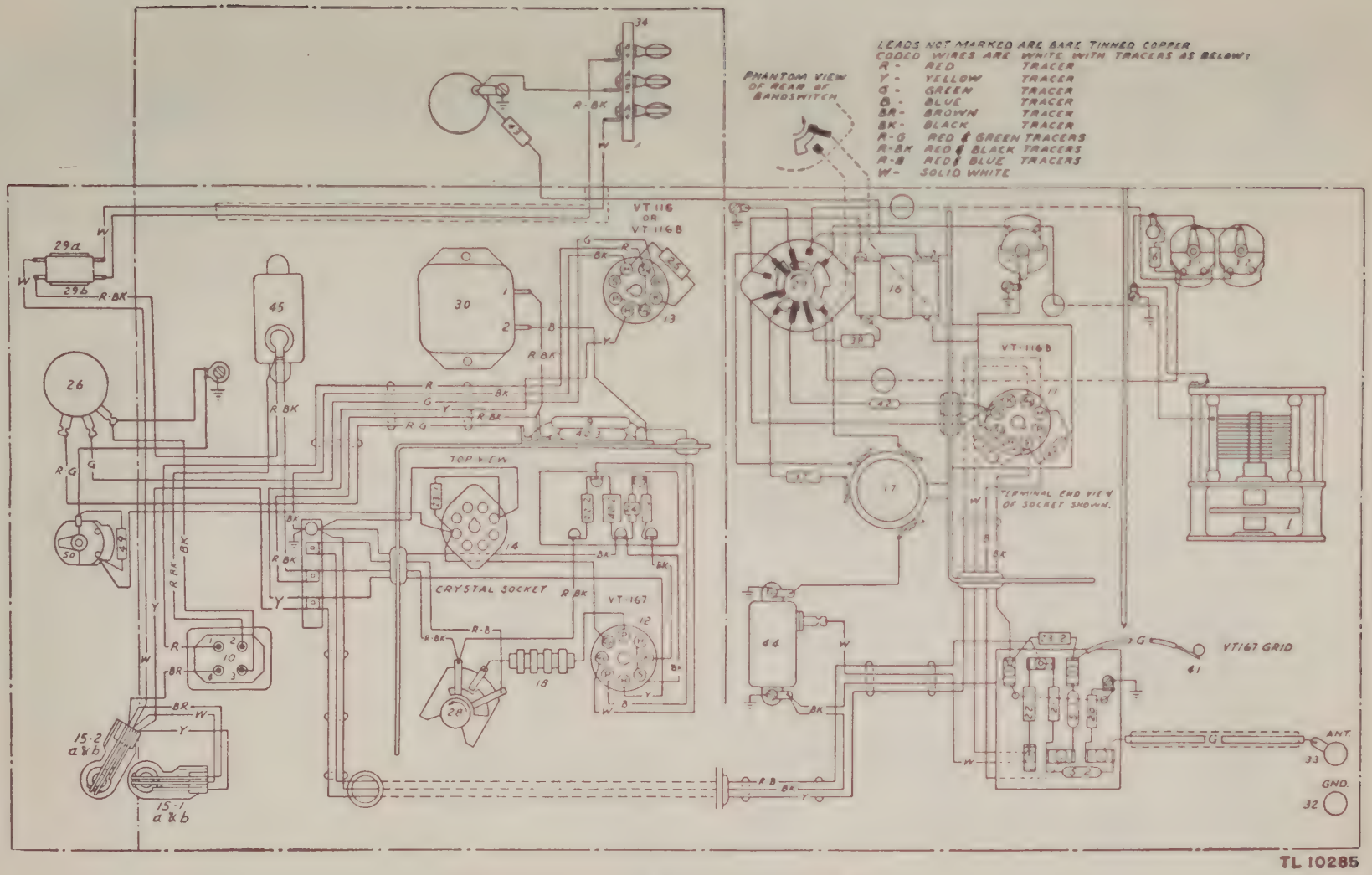


Figure 82. Frequency Meter BC–221–AF, chassis wiring diagram.

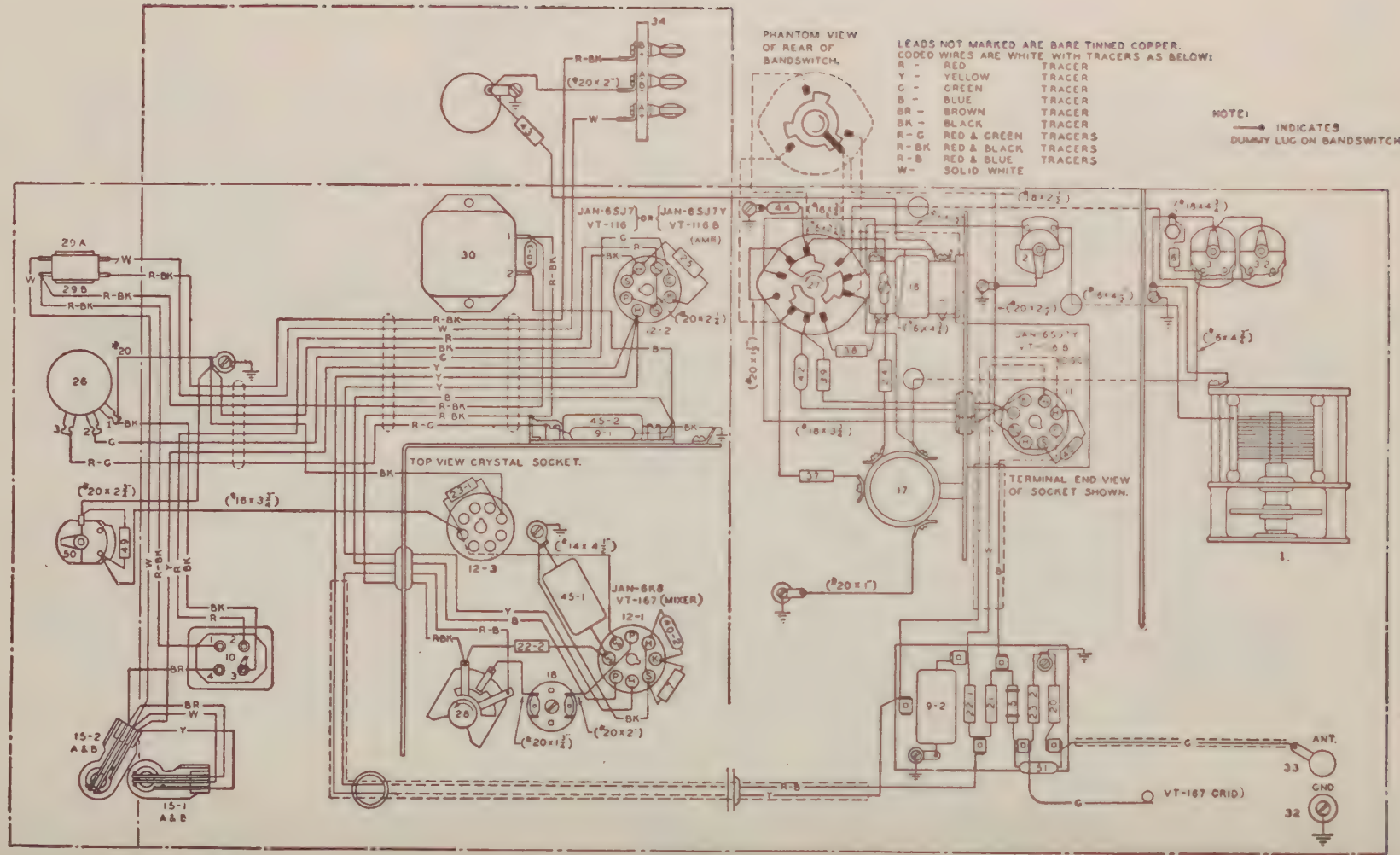

PHANTOM VIEW OF REAR OF BANDSWITCH.
LEADS NOT MARKED ARE BARE TINNED COPPER.
CODED WIRES ARE WHITE WITH TRACERS AS BELOW:
R - RED TRACER
Y - YELLOW TRACER
G - GREEN TRACER
B - BLUE TRACER
BR - BROWN TRACER
BK - BLACK TRACER
R-G RED & GREEN TRACERS
R-BK RED & BLACK TRACERS
R-B RED & BLUE TRACERS
W - SOLID WHITE
NOTE: → INDICATES DUMMY LUG ON BANDSWITCH.
TOP VIEW CRYSTAL SOCKET.
TERMINAL END VIEW OF SOCKET SHOWN.
JAN-6SJ7 VT-116 OR JAN-6SJ7Y VT-116B (AMR)
JAN-6K8 VT-167 (MIXER)
JAN-6S7Y VT-68
VT-167 GRID
ANT.
GND
TL 10634

Figure 83. Frequency Meter BC–221–AH, chassis wiring diagram.

CHAPTER 9

FREQUENCY METER SETS SCR–211–AE AND SCR–211–AG

Section I. DESCRIPTION

239. General

Frequency Meter Set SCR–211–AE and SCR–211–AG have been manufactured by the Philco Corporation on several orders. These sets are similar in all electrical and mechanical details but differ in nomenclature and order numbers as well as in part sizes and designation. For further general information see paragraph 2. The symbol (7) used in this chapter refers to either the SCR–211–AE or the SCR–211–AG.

240. Components

Each frequency Meter Set SCR–211–(7) includes the following component units:

Quantity	Component
1	Frequency Meter BC–211–(7) includes:
	1 Crystal Unit DC–9–P or DC–9–AD (in operating position)*.
	1 Calibration Book MC–177–(7).
	1 Wrench for Bristo No. 8 setscrew (spares compartment).
4	Tube VT–116, type 6SJ7 (two in use, two spare).
2	Tube VT–167, type 6K8 (one in use, one spare).
1	Strap ST–19–A
2	Technical manuals for Frequency Meter Set SCR–211–(7).
1	Cord CD–874 for Headset HS–30–(&).

* Any crystal unit with nomenclature N or higher can be used interchangeably with any frequency meter set with nomenclature N or higher.

Some Frequency Meter Sets SCR–211–AE have been supplied with a spare crystal unit. However, Order No. 23897–Phila–43 was supplied with one Crystal DC–9–P or DC–9–AD in use and no spare.

NOTE. A bag is not furnished with the SCR–211–AE or SCR–211–AG. A suitable cover is supplied with the wooden cabinet and is not considered to be a separate component.

241. Additional Equipment Required

The following equipment, not furnished with the orders, is required to complete each Frequency Meter Set SCR–211–(7):

Quantity	Article
1	Headset HS–30–(&)*.
4	Batteries BA–23.
6	Batteries BA–2.

* If this headset cannot be obtained, use Headset P–18 or P–20.

242. Total Weight

SCR–211–(7), complete and ready for service, weighs approximately 36.24 pounds. For typical dimensions, see figure 27.

243. Power Consumption

All power required for the operation of this

equipment is supplied by the batteries listed in paragraph 241. The current drains under the specified conditions are approximately as follows:

Filaments: 6 volts: 0.85 ampere.
Plates, etc.: 135 volts; 0.012 ampere with operation switch at CRYSTAL.
0.018 ampere with operation switch at OPERATE*.
0.014 ampere with operation switch at CHECK.

* Contrary to the general rule covering this type of meter. Frequency Meter Set SCR–211–(7) places maximum load on the batteries in the OPERATE position of the operation switch.

244. Controls (pars. 2e and 94)

245. Vacuum Tubes

The vacuum tubes used in the Frequency Meter Set SCR–211–(7) are shown in the following tabulation:

Reference	Function	Signal Corps type nomenclature	Commercial equivalent	Base
VT–116.....	Variable frequency oscillator.	VT–116.....	6SJ7.....	Octal
VT–167.....	Crystal oscillator and detector.....	VT–167.....	6K8.....	Octal
VT–116.....	Audio-frequency amplifier.	VT–116.....	6SJ7.....	Octal

251. Reading the Dial (par. 11)

252. Calibration Book MC–177–(7) (par. 12)

253. Operating Circuits (par. 13)

254. Zero Beat Detection (par. 14)

255. Correction in Calibration (par. 15)

The information contained there applies exactly to the Frequency Meter Set SCR–211–(7).

256. Crystal Check Points (par. 16)

257. Frequency Measurements (par. 17)

The proper position of the operation switch is OPERATE for making frequency measurements as described in paragraph 17.

Section II.
INSTALLATION AND OPERATION

246. Initial Procedure (par. 7)

Make sure a spare set of vacuum tubes is installed in the space provided.

247. Installation of Batteries (pars. 8 and 187b)

248. Antenna (par. 9)

249. Headset (par. 10)

The headset necessary to operate Frequency Meter Set SCR–211–(7) is kept in the compartment at the lower front of the cabinet. (See fig. 25.) Headset HS–30–(&) has an impedance of 250 ohms. A headset plug must be inserted into one of the PHONES jacks before the meter will operate.

250. Preparation for Use (par. 70)

258. Precautions During Operation (par. 18)

259. Adjustments for Field Upkeep (par. 19)

Section III. FUNCTIONING OF PARTS

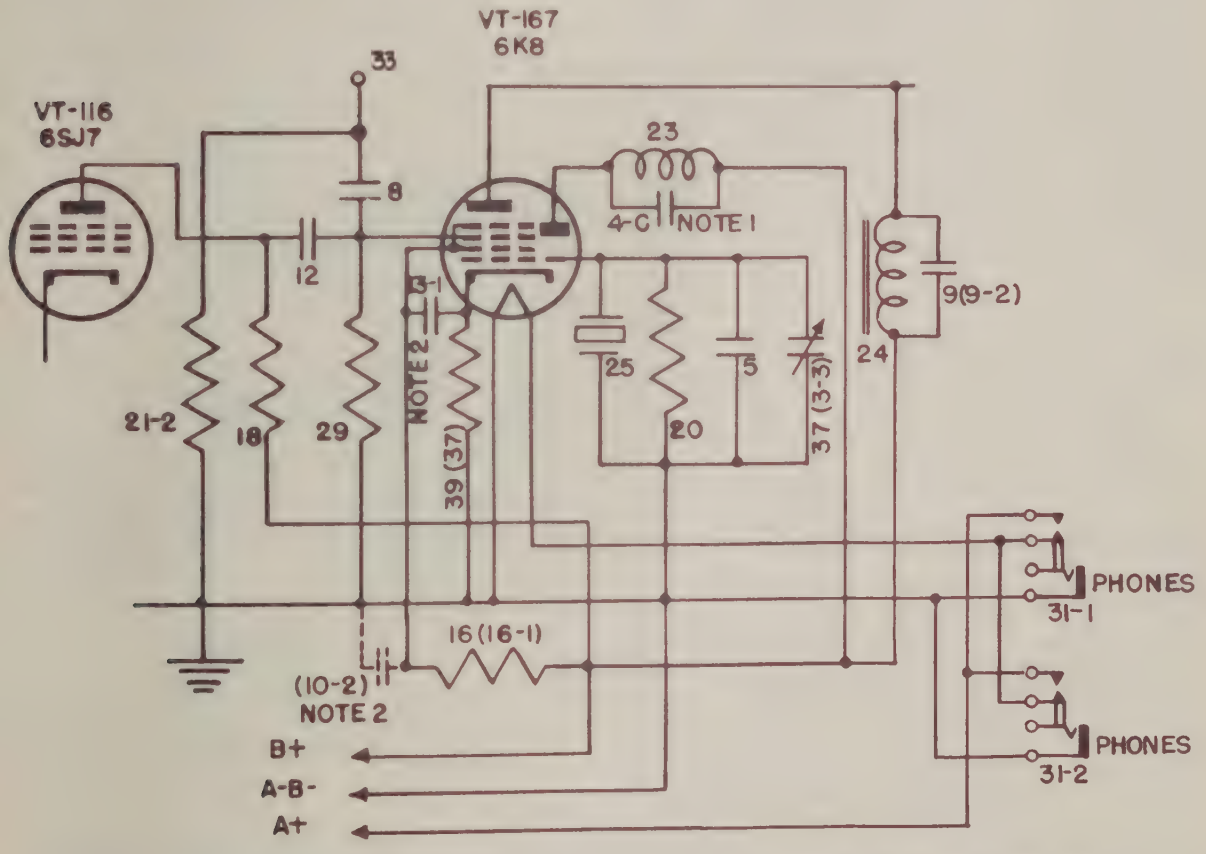
260. General

Frequency Meters BC–221–AE and BC–221–AG are very similar to the meters described in chapters 4 and 7 of this manual and to each other. There are a number of differences in part sizes and designations between the BC–221–AE and BC–221–AG. In order to describe both types at once, a special numbering system is employed in the descriptions to follow in this section. Where there are differences in designation, the numbers in parentheses apply to the BC–221–AG

while the numbers out of parentheses apply to the BC–221–AE. Other differences are covered by footnotes on the functional diagrams. As an example of the numbering system, the designation 39 (37) means part No. 39 of the BC–221–AE and part No. 37 of the BC–221–AG. For further details see figures 87 and 88.

261. Circuit Components (par. 21)

CRYSTAL or CHECK position. The operation switch controls the crystal oscillator by opening or closing its plate voltage circuit. The oscillator circuit is designed to generate considerable harmonic energy so that it can be used to calibrate the variable frequency oscillator at several points over its entire range, as well as to supply whole multiples of 1,000 kc for the calibration of re-



NOTE 1:- THE BY-PASS CAPACITOR, PART NO. 4-C, IS OMITTED IN THE BC-221-AG.

NOTE 2:- PART NO. 13-1 IS OMITTED AND REPLACED BY PART NO. (10-2), SHOWN IN DASHED LINES, IN THE BC-221-AG

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Figure 84. Frequency Meter BC–221–(7), functional diagram, crystal-oscillator circuit.

262. Crystal Circuit

The crystal circuit uses the triode section of Tube VT–167 (6K8). (See fig. 84.) The oscillator operates at the fixed frequency of 1,000 kc when the operation switch 28 is placed in the

ceivers and similar equipment. The necessary plate circuit impedance is built up across choke coil 23 (shunted by capacitor 4–c, in the BC–221–AE only, to provide a low impedance path to ground for high order harmonics of the crystal oscillator fundamental frequency of 1,000

kc). Resistor 20 is the oscillator grid leak and works in conjunction with the tube cathode resistor 39 (37). The variable capacitor 37 (3–3) is connected across the crystal 25 for the purpose of adjusting the frequency of the crystal to a closer point than can be economically obtained by grinding alone. When the frequency meters are adjusted during manufacture, the variable capacitor is set up to produce a frequency of 1000 kc ± 5 cycles at 20° centigrade. The fixed capacitor 5 shunted across the crystal, minimizes any change in fundamental frequency due to small changes in the crystal capacitance. Further reference to figure 84 shows that the output of the crystal oscillator is electron coupled to the antenna through the No. 3 grid of the hexode section of Tube VT–167 and capacitor 8. For further details on the crystal oscillator, see paragraph 22.

a. Coils. The two inductors 22 and 30, in the tuned circuits, are wound upon ceramic forms and the low frequency coil 30 is coated with a special wax to eliminate the influence of changing atmospheric conditions on the stability of the meter. The active terminals of these coils are connected across the terminals of the main tuning capacitor 1 by means of the band selector (FREQ. BAND LOW-HIGH) switch 27. Each coil and the tuning capacitor, together with other capacitors mentioned below, constitute the resonant circuit that determines the output frequency. The correct operating bias on the control grid of the oscillator tube is provided by the capacitor and resistor combination 7 and 19 which connects to a tap on either coil through the band selector switch 27. The frequency of oscillation is made relatively independent of variations in tube characteristics when the grid

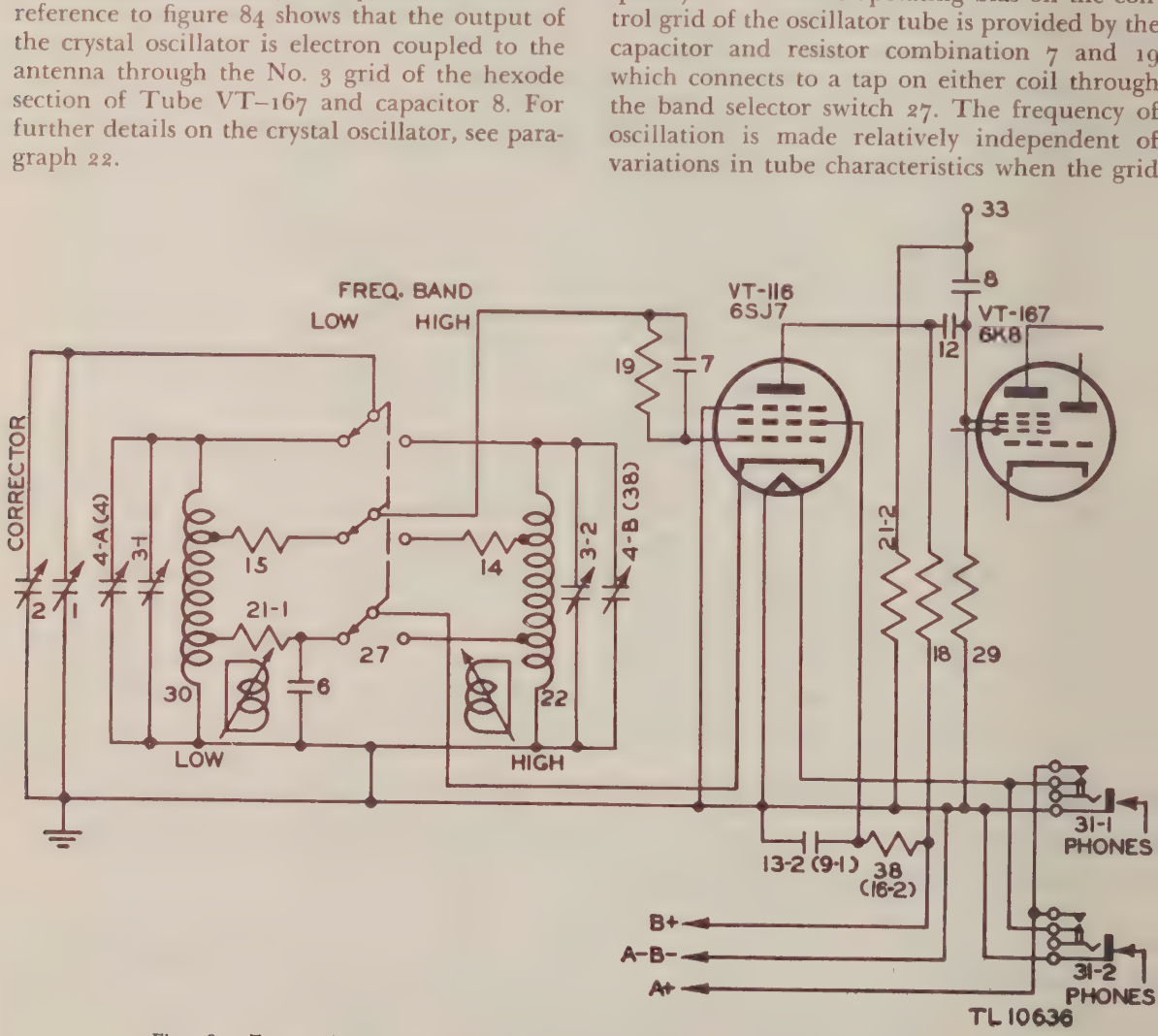


Figure 85. Frequency Meter BC–221–(7), functional diagram, variable frequency oscillator circuit.

263. Variable Frequency Oscillator Circuit (par. 23)

Tube VT–116 (6SJ7) is used in an electron coupled circuit as the variable frequency oscillator. (See fig. 85.)

connection is tapped down an appreciable distance from the high-potential end of the coil. The resistors 14 and 15, which carry little current, are connected in series with the grid circuit taps on the coils and serve to stabilize the opera-

tion of the oscillator circuit by suppressing undesirable oscillations. The second coil tap, located near the grounded end of each coil and connected to the cathode of the oscillator tube through another set of contacts on switch 27, serves to control the amount of feedback in the oscillator circuit. The resistor 21–1 which is in series with this connection on coil 30 applies additional cathode bias to the grid of the oscillator tube. This cathode bias resistor is bypassed to ground by capacitor 6. The short-circuited windings shown at the end of each of the coils (fig. 85) are inductive temperature-compensating devices used to obtain additional temperature stability. Resistor 18 is the oscillator tube plate circuit load. The voltage developed across it is coupled to detector-converter Tube VT–167 through capacitor 12, or to the antenna through capacitors 12 and 8 in series. Resistor 38 (16–2) is the screen grid dropping resistor, and part 13–2 (9–1) is the screen grid bypass capacitor to ground.

b. Band Selector Switch. Switch 27 is a double-throw, triple-pole switch with all contacts mounted on ceramic plates. In order to minimize abnormal capacitive effects, all contacts are made as small as possible and are of the self-aligning, self-wiping type. The switch has a heavy detent which accurately locates the rotor plate in either one of its two positions.

c. Corrector Control. Capacitor 2, the CORRECTOR control, with a range of 1.2 micromicrofarads (1.2$\mu\mu$f), enables the operator to control the variable capacitance of the tuned circuit in order to compensate for slight changes in the circuit. (See par. 94f.)

d. Trimming Capacitors. The trimming capacitors are parts 3–1 and 3–2. The associated thermal compensator capacitors, part Nos. 4–A (4) and 4–B (38), reduce changes in circuit capacitance due to temperature changes. Since the coils are compensated for changes in inductance (par. 263a), frequency drifts due to temperature changes are negligible. The trimming capacitors are adjusted at the factory to build up the fixed capacitance of the LOW and HIGH frequency circuits to the exact values called for by the design of the variable tuning capacitor.

Caution: Do not tamper with these trimmer capacitor settings. To do so will throw the meter completely off calibration.

e. Oscillator Function. (1) The variable frequency oscillator circuit is in operation at the CHECK and OPERATE positions of the operation switch 28. (See figs. 87 and 88.)

(2) At the CHECK position, the output of oscillator Tube VT–116 (6SJ7) is applied to one of the grids of detector-converter Tube VT–167 (6K8) where it is mixed with the output frequency of the crystal circuit. The result is a frequency equal to the difference of the two and is used to adjust the frequency of the oscillator by means of the CORRECTOR control.

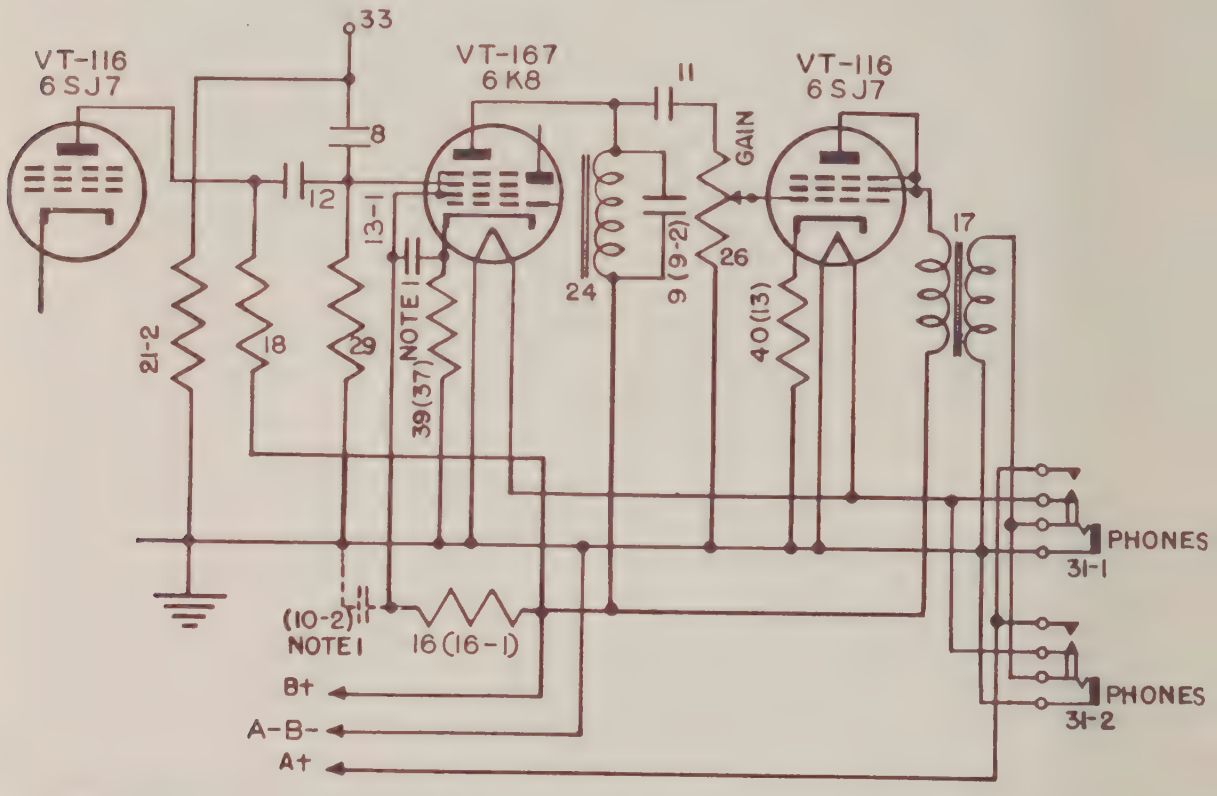
(3) At the OPERATE position, the variable frequency oscillator is in operation, while the crystal oscillator is not. If the antenna is in position, the frequency meter may be used to receive or send any frequency in its range; that is, it may be used as a radio receiver or transmitter.

264. Detector Tube Circuit

It has been stated that the triode section of Tube VT–167 (6K8) is used in the crystal-oscillator circuit. The remaining hexode section of the tube of which the No. 1 grid is tied to the control grid of the triode section, is used as a high gain screen grid detector with hexode grid No. 3 acting as the control grid. The joint action of grids No. 1 and 3 produces electron coupling of the signals on the two grids. (See fig. 86.) Resistor 29 is the detector tube grid leak. Resistor 16 (16–1) supplies voltage to the screen grid of Tube VT–167 (6K8). Capacitor 13–1, in the BC–221–AE, bypasses the screen grid to the cathode. Capacitor 10–2, in the BC–221–AG, bypasses the screen grid to ground. The antenna post 33 is connected to ground through resistor 21–2. The r-f voltage, developed across the load resistor 18 in the plate output circuit of the variable frequency ocillator, is coupled to the No. 3 grid of this detector through a small fixed capacitor 12. The antenna post 33 is also coupled to the No. 3 grid through the coupling capacitor 8. As a result of these couplings to the control grid, the detector mixes the variable frequency oscillator output with the fundamental and successive harmonics of the crystal when the operation switch 28 is in the CHECK position, and with the radio transmitter frequency to be measured when the switch is in the OPERATE position. By reference to figures 85 and 86 it can be seen that the antenna post 33 is also coupled to the variable frequency oscillator output through capacitors 8 and 12 in series. Thus, the antenna connection serves the dual purpose of a detector input terminal for the measurement of frequencies of external origin and of a variable frequency oscillator output terminal for use in calibrating receivers. When the unit is employed

for the latter purpose, a minimum of 2,000 microvolts of radio frequency energy will be available between the antenna post 33 and ground (the chassis) at any frequency within the calibrated range.

mary of the audio-output transformer 17. The secondary of the audio-output transformer connects to the PHONES jacks 31–1 and 31–2 and ground. This is done so that no d-c voltage will be present in the output circuit. The output



NOTE 1: PART NO. 13-1 IS OMITTED & REPLACED BY PART NO. (10-2) SHOWN IN DASHED LINES, IN THE BC-221-AG.

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Figure 86. Frequency Meter BC–221–(7), functional diagram, detector and audio-amplifier circuits.

265. Audio-Amplifying Circuit (par. 25) The detector plate works into an audio-frequency choke coil 24, which is bypassed by the capacitor 9 (9–2) to reduce the response to high frequencies. The beat frequency voltages built up across the choke coil are coupled through capacitor 11 and the GAIN control potentiometer 26 to the grid of Tube VT–116 (6SJ7) connected as a triode. The grid of Tube VT–116 returns to ground through the potentiometer 26, and the necessary grid bias voltage is obtained by means of the cathode dropping resistor 40 (13). The plate (tied to the suppressor and screen grids) of Tube VT–116 returns to the positive plate supply voltage through the primary of the audio-output transformer 17. The secondary of the audio-output transformer connects to the PHONES jacks 31–1 and 31–2 and ground. This is done so that no d-c voltage will be present in the output circuit. The output circuit is designed for the use of the low impedance type Headset HS–30–(&). Under certain conditions the high impedance type Headset P–18 or P–20 might be substituted for the HS–30–(&), but the results obtained will, in general, be inferior.

266. Power Supply Circuit (figs. 87 and 88) All power required for the operation of the meter is introduced through the battery terminal board 36, located at the end of the battery cable. The common negative filament and negative plate battery leads are connected to the middle terminal which is grounded to the chassis. A fabricated wiring harness and a fiber terminal

board used in connection with the battery harness are provided for intercell and filament battery to terminal board connections. The operation switch 28 closes both the positive 6-volt supply (A+) and the positive 135-volt supply (B+). The positive 6-volt supply (A+) is closed to the vacuum tube filaments through the auxiliary switches on the PHONES jacks 31–1 and 31–2 when a headset plug is inserted in one of the jacks. Since the door covering the control panel cannot be closed with the headset plug in place, the *A* and *B* batteries cannot be discharged even though the operation switch is left in an active position when the meter is removed from service.

Section IV. MAINTENANCE

267. General

For all details of field maintenance, see paragraphs 26, 27, and 28.

Section V. SUPPLEMENTARY DATA

268. Tabular List of Maintenance Parts

a. Frequency Meter BC–221–AE.

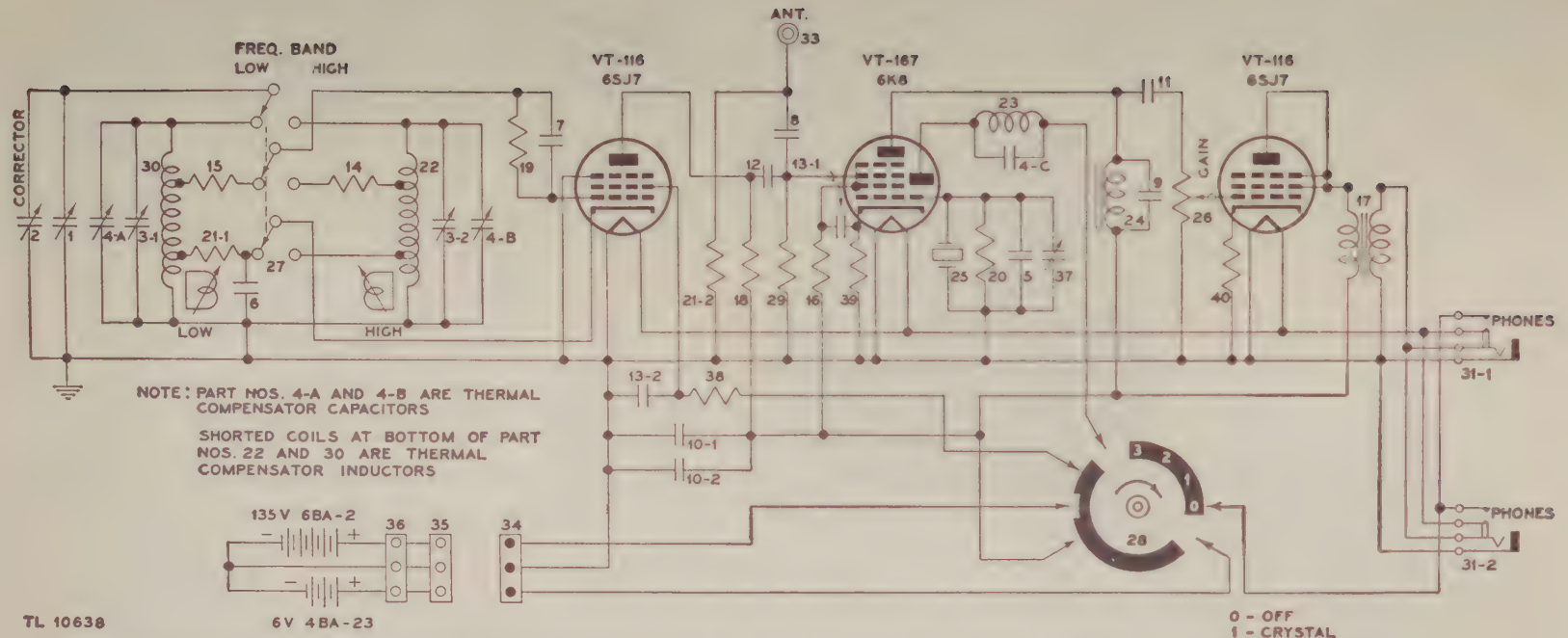
Note. Order maintenance parts by stock number, name, and description.

Ref. No. symbol	Signal Corps stock No.	Name of part and description	Quan. per equip.	Lowest maint. echelon
	2Z481AE	BAG: BG–81–AE; carrying	1	3d
	2Z551–160	BAG: BG–160–(&)/S; available for amphibious operations	1	Orgn stock
	3A2	BATTERY: BA2; 22.5=v	6	3d
	3A23	BATTERY: BA23; 1.5=v	4	3d
	3E1605–6.5	CORD: CD–605; 6½=ft.; 2=cond.; PL–55 at one end; Transformer C–410 at other	1	3d
	3E1874	CORD: CD–874; 6½=ft.; 2=cond.; PL–55 on one end; JB–47 on other end	1	3d
	2B830(&)	HEADSET: HS–30–(&); component HEADSET: HS–30–(&); repair parts	1	Orgn stock
	2B1300	INSERT: M–300	2	Orgn stock
	2Z9019A	STRAP: ST–19–A	1	3d

b. FREQUENCY METER BC–221–AG.

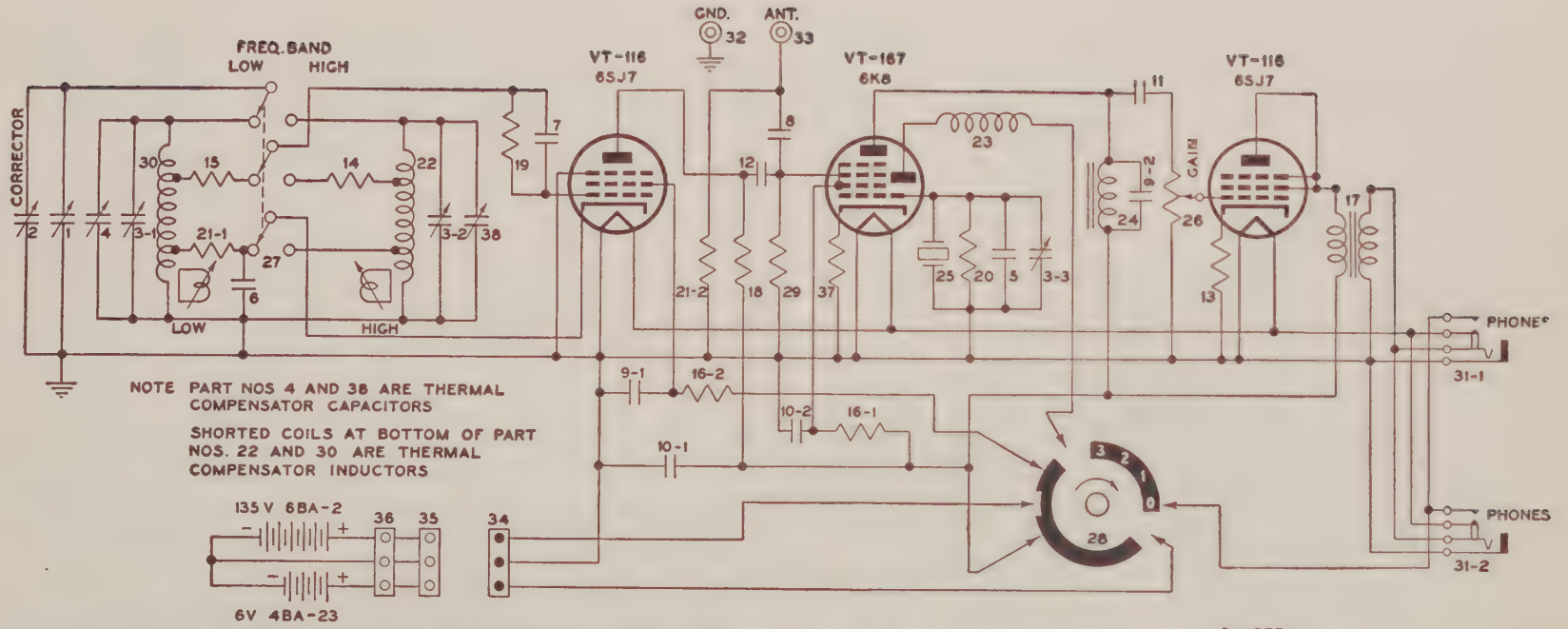
NOTE. Order parts by stock number, name, and description.

Reference No. Symbol	Signal Corps Stock No.	Name of Part and Description	Quantity per Equip.	Lowest Maintenance Echelon
	2Z481AG	BAG: BG–81–AG; carrying	1	3d
	2Z551–160	BAG: BG–160 (&) /S; available for amphibious operations	1	Orgn stock
	3A2	BATTERY: BA2; 22.5=v	6	3d
	3A23	BATTERY: BA23; 1.5=v	4	3d
	3E1605–6.5	CORD: CD–605; 6½=ft.; 2=cond.; PL–55 at one end; Transformer C–410 at other.	1	3d
	3E1874	CORD: CD–874; 6½=ft.; 2=cond.; PL–55 on one end; JB–47 on other end	1	3d
	2B830(&)	HEADSET: HS–30–(&); component HEADSET: HS–30–(&); repair parts	1	Orgn stock
	2B1300	INSERT: M–300	2	Orgn stock
	2Z9019A	STRAP: ST–19–A	1	3d



REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	200 μμf	9	.002 μf	17	OUTPUT TRANS	25	CRYSTAL	34	POWER PLUGS
2	1.2 μμf	10–1&2	.5 μf	18	50,000 OHM	26	0.5 MEGOHM	35	POWER JACKS
3–1&2	15 μμf	11	.25 μf	19	330,000 OHM	27	SWITCH	36	BATTERY TERM.
4–A,B,&C	10 μμf	12	50 μμf	20	1 MEGOHM	28	SWITCH	37	12 μμf
5	6.5 μμf	13–1&2	.001 μf	21–1&2	5,000 OHM	29	470,000 OHM	38	20,000 OHM
6	250 μμf	14	27 OHM	22	25.84 MICROHY	30	7.06 MILLIHY	39	150 OHM
7	15 μμf	15	1,500 OHM	23	735 MICROHY	31–1&2	JACK	40	1,000 OHM
8	25 μμf	16	10,000 OHM	24	40 HENRYS	33	BINDING POST		

Figure 87. Frequency Meter BC–221–AE, schematic diagram.



REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	200 μμf	9–1&2	.001 μf	17	OUTPUT TRANS	25	CRYSTAL	33	BINDING POST
2	1.2 μμf	10–1&2	.25 μf	18	50,000 OHM	26	0.5 MEGOHM	34	POWER PLUGS
3–1,2,&3	12 μμf	11	.02 μf	19	330,000 OHM	27	SWITCH	35	POWER JACKS
4	10 μμf	12	50 μμf	20	1 MEGOHM	28	SWITCH	36	BATTERY TERM.
5	6 μμf	13	1000 OHM	21–1&2	5,000 OHM	29	470,000 OHM	37	150 OHM
6	250 μμf	14	27 OHM	22	25.84 MICROHY	30	7.06 MILLIHY	38	10 μμf
7	15 μμf	15	1500 OHM	23	1.0 MILLIHY	31–1&2	JACK		
8	25 μμf	16–1&2	10,000 OHM	24	150 HENRYS	32	BINDING POST		

Figure 88. Frequency Meter BC–221–AG, schematic diagram.

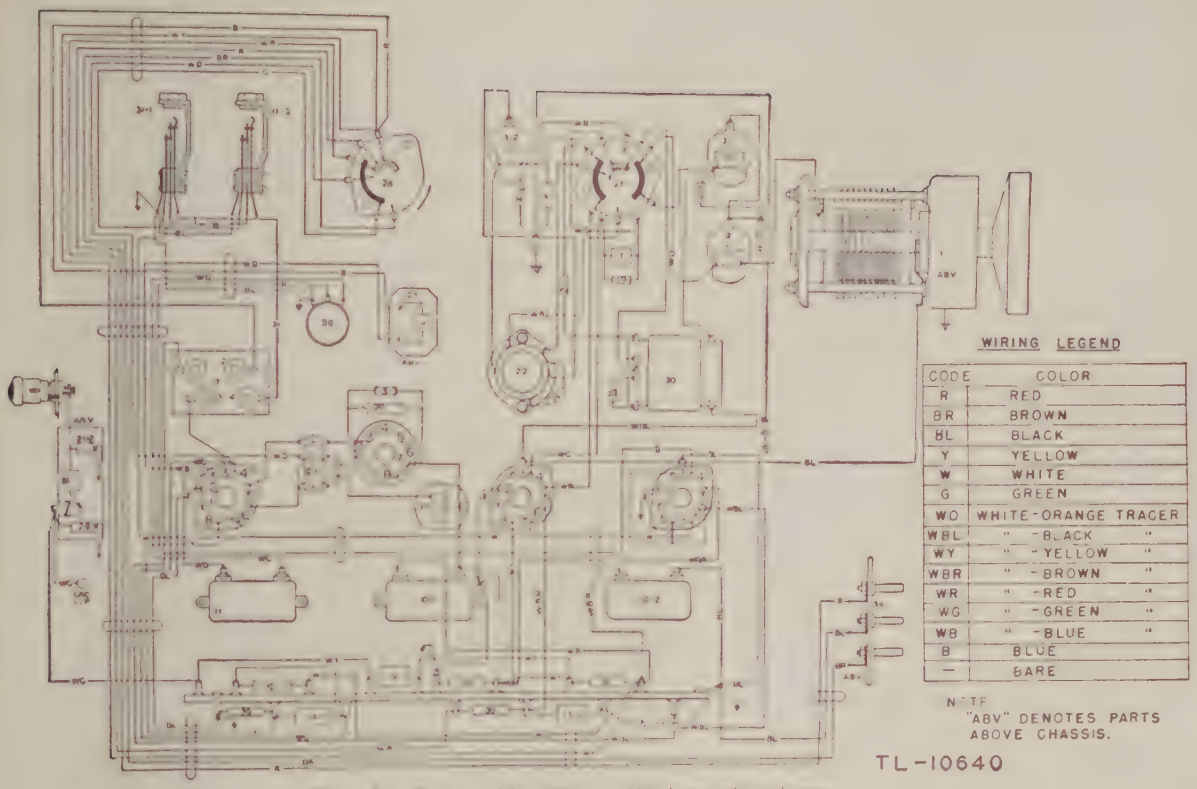


Figure 89. Frequency Meter BC-221-AE, chassis wiring diagram.

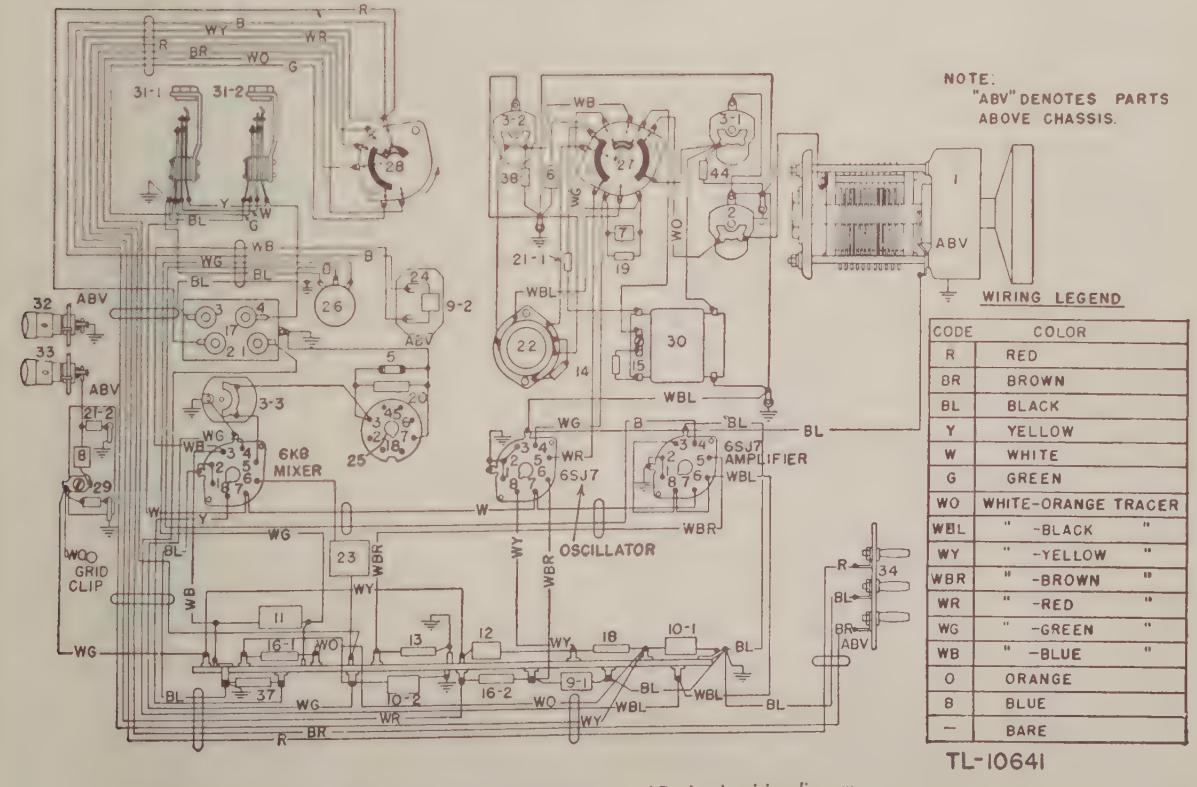


Figure 90. Frequency Meter BC-221-AG, chassis wiring diagram.

CHAPTER 10

FREQUENCY METER SET SCR–211–AK

Section I. DESCRIPTION

269. General

Frequency Meter Set SCR–211–AK has been manufactured by the Philco Radio Corporation on several orders. The SCR–221–AK is the first of a new series of frequency meter sets containing a modulator unit and a WARM-UP position of the operation switch. When the operation switch is at MODULATE, the output of the variable frequency oscillator is modulated at a frequency of approximately 375 cycles. This provides a means of calibrating and testing receivers which are not equipped with a c-w oscillator. In the WARM-UP position of the operation switch, only the filament of variable frequency oscillator Tube VT–116 (6SJ7) is turned on. This eliminates any unnecessary drain on the *A* and *B* batteries during the initial warm-up period. As a result there is a considerable saving in battery life. For further general information see paragraph 2.

270. Components

Each Frequency Meter Set SCR–211–AK includes the following component units:

Quantity	Component
1	Frequency Meter BC–221–AK includes: 1 Crystal Unit DC–9–P or DC–9–AD (in operating position)*. 1 Calibration Book MC–177–AK. 1 Wrench for Bristo No. 8 setscrew (spares compartment).
4	Tube VT–116, type 6SJ7 (two in use, two spare).
2	Tube VT–167, type 6K8 (one in use, one spare).
1	Cord CD–874, for Headset HS–30–(&).
1	Strap ST–19–A.
2	TM 11–300AG for Frequency Meter Sets SCR–211–AG and SCR–211–AK

* Any crystal unit with nomenclature N or higher can be used interchangeably with any frequency meter set with nomenclature N or higher.

NOTE. A bag is not furnished with the SCR–211–AK. A suitable cover is supplied with the wooden cabinet and is not considered to be a separate component.

271. Additional Equipment Required

The following equipment, not furnished with the orders, is required to complete each Frequency Meter Set SCR–211–AK:

Quantity	Article
1	Headset HS–30–(&)*.
6	Batteries BA–2.
4	Batteries BA–23.

* If Headset HS–30–(&) cannot be obtained, Headset HS–33 may be substituted.

272. Total Weight

Frequency Meter Set SCR–211–AK, complete and ready for service, weighs approximately 36 pounds. For typical dimensions, see figure 27.

273. Power Consumption

All power required for the operation of this equipment is supplied by the batteries listed in paragraph 271. The current drains under the specified conditions are approximately as follows:

Filaments: 6.0 volts; 0.85 ampere.
0.30 ampere with operation switch at WARM-UP.

Plates, etc.: 135 volts; 0.000 ampere with operation switch at WARM-UP.
0.012 ampere with operation switch at CRYSTAL.
0.018 ampere with operation switch at OPERATE.
0.017 ampere with operation switch at MODULATE.
0.014 ampere with operation switch at CHECK.

NOTE. Contrary to the general rule covering this type of meter, the SCR–211–AK places maximum load on the batteries in the OPERATE position of the operation switch.

Battery life varies greatly depending upon the length of individual periods of operation, the length of time the batteries are allowed to rest between successive periods of operation, and the temperature of the place where the instrument is stored or used. High temperatures and long individual periods of operation will shorten battery life. The WARM-UP position of the operation switch should be used during warming-up periods or during stand-by periods, not exceeding one hour, when it is desired to keep the frequency stabilized.

274. Controls (par. 2e)

When the snap latches are released and the front cover lowered, the control panel is exposed. The calibration book is exposed when the inside portion of the front cover is opened. There are six operating controls (fig. 8):

a. Two PHONES jacks allow for observations by two persons at the same time; for example, student and instructor. A headset must be plugged into one of the jacks before the meter can be set into operation because of the series filament supply switches built into the jacks.

b. The GAIN control is a volume control used to adjust the input voltage to the audio-amplifier tube, and in turn the level of sound in the headset.

c. The OFF-WARM-UP-CRYSTAL-OPERATE-MODULATE-CHECK control is the operation switch of the BC–221–AK. In the OFF position, both the *A* and *B* battery circuits are open. In the WARM-UP position, the *A* battery circuit, connected through the series filament supply switches built into the PHONES jacks, is closed to the filament of the variable frequency oscillator tube only, and the *B* battery circuit remains open. In the CRYSTAL position, the *A* battery circuit to all tubes is closed and remains closed for all succeeding positions of the switch. The *B* battery circuit is closed to all tubes with the exception of the variable frequency oscillator. In the OPERATE position, the *B* battery circuit is closed to all tubes with the exception of the crystal-oscillator portion of the detector-converter tube. In the MODULATE position, in addition to converting the audio-amplifier circuit to an audio-frequency oscillator circuit, the operation switch causes the *B* battery circuit to be closed to all tubes with the exception of the crystal oscillator, as in the OPERATE position, and the plate circuit of the variable frequency oscillator is connected to the modulator. In the CHECK position, the audio-amplifier circuit is restored to normal conditions and the *B* battery circuit is closed to all tubes. The OPERATE position places maximum load on the batteries; the WARM-UP position, minimum load on the batteries.

d. The FREQ. BAND LOW-HIGH switch permits the selection of the appropriate band of operation of the variable frequency oscillator, as indicated by the frequency being checked or calibrated.

e. The frequency of the variable frequency oscillator is controlled by the setting of the dial labelled DIAL UNITS which is graduated into one hundred divisions. One revolution of the DIAL UNITS dial moves the DIAL HUNDREDS dial one division. (See par. 11.)

f. The CORRECTOR knob controls a small variable capacitor across the variable frequency oscillator tuned circuit, and is used to compensate for small changes in capacity brought about by temperature, humidity, and mechanical changes. It is adjusted at each CRYSTAL CHECK POINT to make calibration of the instrument as accurate as possible over that part of the scale centered at a given CRYSTAL CHECK POINT and extending halfway to the next higher and next lower CRYSTAL CHECK POINTS.

275. Vacuum Tubes

The vacuum tubes used in the Frequency Meter Set SCR–211–AK are shown in the following tabulation:

Reference	Function	Signal Corps Type Nomenclature	Commercial Equivalent	Base
VT–116.....	Variable frequency oscillator.	VT–116.....	6SJ7.....	Octal
VT–167.....	Crystal oscillator and detector.	VT–167.....	6K8.....	Octal
VT–116.....	Audio-frequency amplifier and oscillator.	VT–116.....	6SJ7.....	Octal

Section II.

INSTALLATION AND OPERATION

276. Initial Procedure (par. 7)

Make sure a spare set of tubes is installed in the space provided.

277. Installation of Batteries (pars. 8 and 187b)

278. Antenna (par. 9)

279. Headset (par. 10)

The headset necessary to operate Frequency Meter Set SCR–211–AK is kept in the compartment at the lower front of the cabinet. (See fig. 25.) Headset HS–30–(&) has an impedance of 250 ohms. A headset plug must be inserted in one of the PHONES jacks before the meter will operate.

280. Preparation for Use

a. To start the meter, insert the headset plug into a PHONES jack and turn the operation switch to the WARM-UP position.

b. After starting the set by the method described above, allow 15 minutes for variable frequency oscillator Tube VT–116– to warm up.

c. In order to test for normal operating conditions, set the operation switch knob at CHECK. While rotating the DIAL UNITS dial, listen in the headset for tones of increasing and decreasing pitch. These different tones are produced by the changing variable oscillator frequency beating with various crystal harmonics. The presence of these tones indicates normal operation.

281. Reading the Dial (par. 11)

282. Calibration Book MC–177–AK (par. 12)

283. Operating Circuits (par. 13)

The BC–221–AK contains one principal operating part in addition to the parts described in paragraph 13: the audio oscillator-modulator, which generates an audio voltage for modulating the r-f signal output of the variable frequency oscillator.

284. Zero Beat Detection (par. 14)

285. Correction in Calibration (par. 15)

The information contained there applies exactly to Frequency Meter BC–221–AK.

286. Crystal Check Points (par. 16)

287. Frequency Measurements (par. 17)

The proper position of the operation switch is OPERATE for making frequency measurements as described in paragraph 17. The modulation feature, provided in the BC–221–AK, makes possible the following additional measurements:

a. To Measure the Frequency to Which a Receiver Is Tuned, When Receiver Is Not Equipped With a C-w Oscillator. (1) Put the meter in operation as instructed in paragraph 280.

(2) Place the antenna of the frequency meter near and parallel to the antenna of the receiver.

(3) Turn the operation switch to MODULATE.

(4) Vary the main tuning dial of the frequency meter until a 375-cycle note is heard in the speaker or headset of the receiver.

(5) Determine the frequency at this dial setting from the calibration book and calibrate the

meter at the nearest CRYSTAL CHECK POINT.

(6) Reset the operation switch on the frequency meter to MODULATE and adjust the main tuning dial until the 375-cycle tone is heard again in the speaker of the receiver.

(7) If the signal tunes broadly, that is, if it is audible over several divisions of the DIAL UNITS dial of the frequency meter, decrease the coupling between the frequency meter and the receiver by moving the frequency meter antenna farther away from the antenna of the receiver. As the coupling is decreased, the signal will tune more sharply, and will be audible over a very small portion of the DIAL UNITS dial. The sharper the tuning, the greater will be the accuracy of the measurement.

(8) Adjust the DIAL UNITS dial for maximum signal in the speaker or headset of the receiver, and lock the dial by turning the dial lock to the right.

(9) Observe the dial setting and determine the frequency corresponding to this setting from the calibration book. If the exact frequency is not given, determine it by interpolation as instructed in paragraph 12e.

b. To Tune Receiver, Not Equipped With C-w Oscillator, to a Desired Frequency. (1) Put the meter in operation as instructed in paragraph 280.

(2) Place the antenna of the frequency meter near and parallel to the antenna of the receiver.

(3) Turn the operation switch to CHECK.

(4) Set the FREQ. BAND switch to the proper band, either LOW or HIGH.

(5) Select the proper dial setting for the desired frequency from the calibration book. Then set the DIAL UNITS dial of the meter to the CRYSTAL CHECK POINT nearest this frequency.

(6) Correct the frequency meter by adjusting the CORRECTOR control until zero beat is obtained.

(7) Turn the operation switch to MODULATE.

(8) Set the DIAL UNITS dial of the frequency meter to the desired frequency point. Lock the dial by turning the dial lock to the right.

(9) Rotate the receiver tuning dial until the signal from the frequency meter is picked up, as indicated by a 375-cycle note in the speaker or headset.

(10) For greatest accuracy, the coupling between the receiver and frequency meter should be adjusted so that the signal tunes sharply on the receiver. At this point, the receiver will be tuned to within a few cycles of the frequency being generated by the frequency meter.

c. Miscellaneous Measurements. Other uses of the MODULATE position of the frequency meter may occur to the operator. For example, the frequency meter may be used to perform an emergency alignment on a receiver when a regular signal generator is not available. No attenuator is included in the frequency meter, however. Consequently the only means of controlling the input signal to the receiver that is being aligned, is to vary the coupling between the frequency meter and the antenna attached to the receiver. If proper allowances are made for this fact, the frequency meter may be used very conveniently as a signal generator, and the output frequencies obtained will be extremely accurate, much more so than can be expected from the average signal generator.

288. Precautions During Operation (par. 18)

289. Adjustments for Field Upkeep (par. 19)

Section III. FUNCTIONING OF PARTS

290. General

The BC–221–AK is very similar to the BC–221–AG described in chapter 9 of this manual with regard to the operation of the variable frequency oscillator, the detector and crystal oscillator, and the audio-amplifier circuits. A six-position operation switch is employed, however, instead of the four-position switch which was used on earlier models made by the same manufacturer. This six-position switch controls two additional circuits, one for the modulator and one for the filament of the variable frequency oscillator tube. At the WARM-UP position of the switch, only the filament of variable frequency oscillator Tube VT–116 (6SJ7) draws current. In the MODULATE position, the circuit of the audio-amplifier stage is changed to that of an audio oscillator which is coupled to the plate circuit of the variable frequency oscillator so that modulation of the r-f output will take place. (See fig. 94.)

291. Circuit Components (par. 21)

The circuit of Frequency Meter BC–221–AK contains one component part in addition to those given in paragraph 21: The audio oscillator-

modulator circuit, which generates an audio-frequency voltage for the modulation of the r-f output of the meter.

292. Crystal Circuit

The crystal circuit uses the triode section of Tube VT–167 (6K8) shown in figure 91. The oscillator operates at the fixed frequency of 1,000 kc when the operation switch 28 is placed in the CRYSTAL or CHECK position. The operation switch controls the crystal oscillator by opening or closing its plate voltage circuit. The oscillator circuit is designed to generate considerable harmonic energy so that it can be used to calibrate the variable frequency oscillator at several points over its entire range, as well as to supply whole multiples of 1,000 kc for the calibration of receivers and similar equipment. The necessary plate circuit impedance is built up across the choke coil 23, inclosed in a metal can. Resistor 20 is the oscillator grid leak and works in conjunction with the tube cathode resistor 37. The variable capacitor 3–3 is connected across the crystal 25 for the purpose of adjusting the frequency of the crystal to a closer point than can be economically obtained by grinding alone. When the frequency meters are adjusted during manufacture, the variable capacitor is set up to produce a frequency of 1,000 kc ± 5 cycles at 20° centigrade. The fixed capacitor 5, shunted across the crystal, minimizes any change in fundamental frequency due to small changes in the crystal capacitance. For further details on the crystal oscillator see paragraph 22.

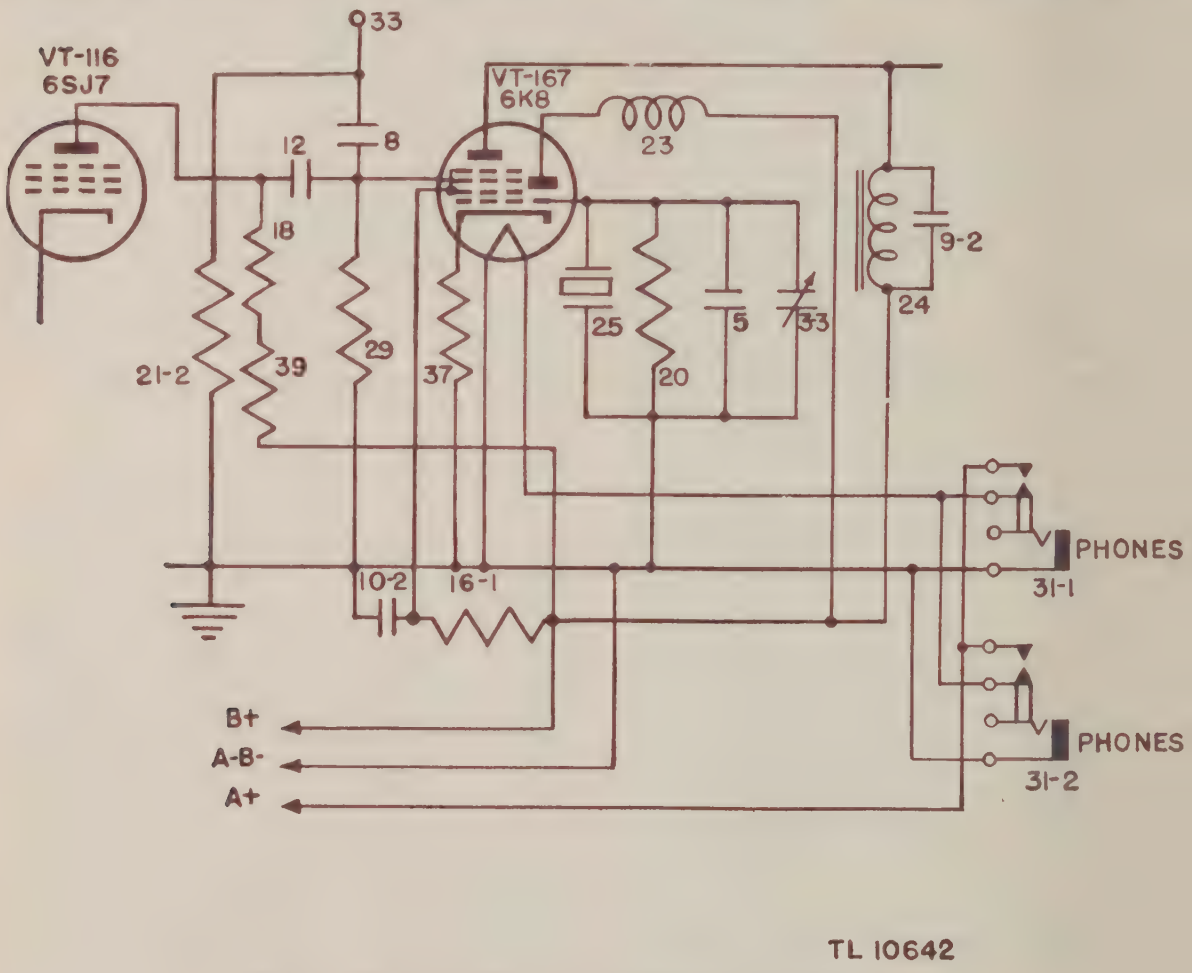


Figure 91. Frequency Meter BC–221–AK, functional diagram, crystal-oscillator circuit.

293. Variable Frequency Oscillator Circuit (par. 23)

Tube VT–116 (6SJ7) is used in an electron coupled circuit as a variable frequency oscillator. (See fig. 92.)

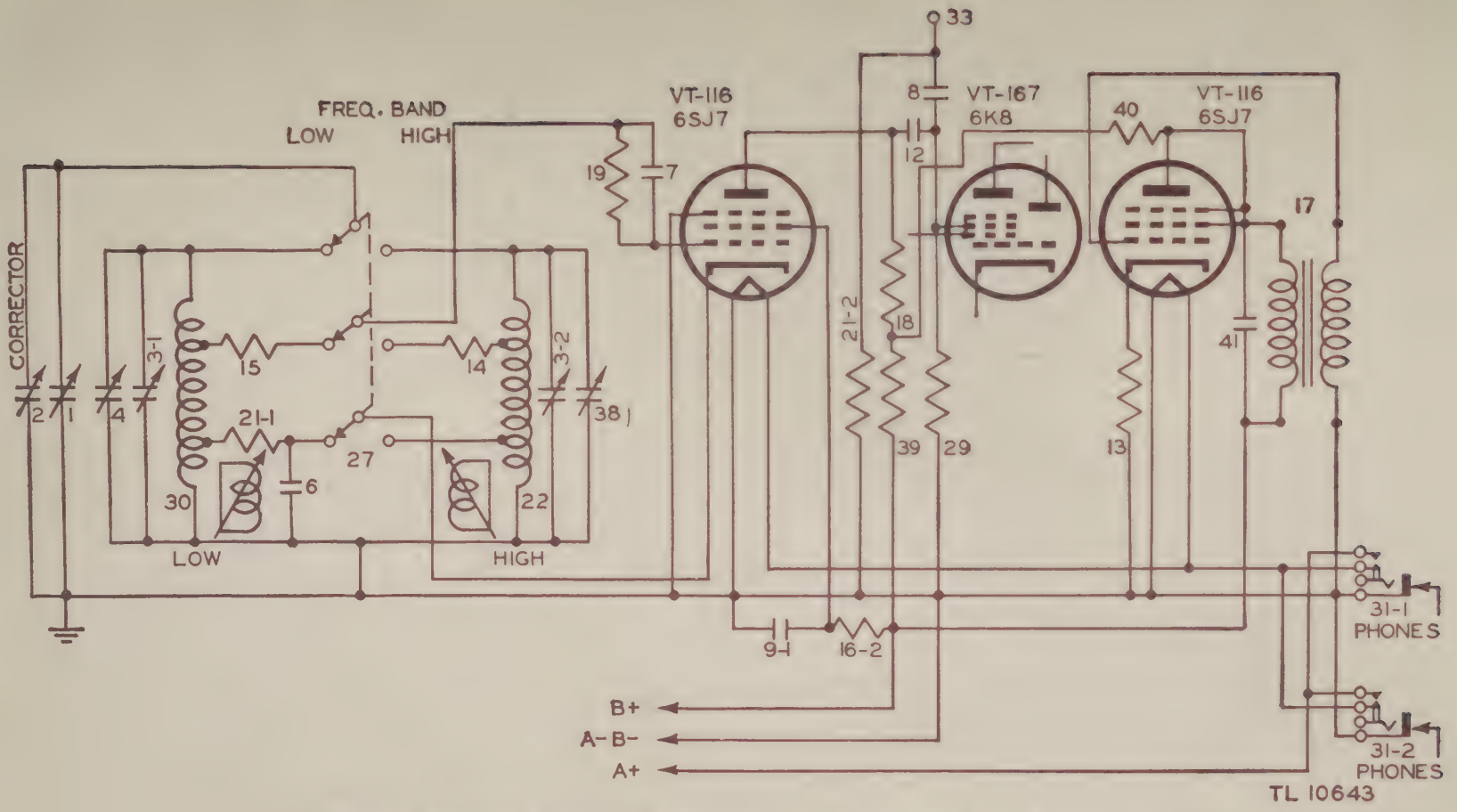


Figure 92. Frequency Meter BC–221–AK, functional diagram, variable frequency oscillator and audio-modulator circuits.

a. Coils. The two inductors 22 and 30, in the tuned circuits, are wound upon ceramic forms and the LOW frequency coil 30 is coated with a special wax to eliminate the influence of changing atmospheric conditions on the stability of the meter. The active terminals of these coils are connected across the terminals of the main tuning capacitor 1 by means of the band selector (FREQ. BAND LOW-HIGH) switch 27. Each coil and the tuning capacitor, together with other capacitors mentioned below, constitute the resonant circuit that determines the output frequency. The correct operating bias on the control grid of the oscillator tube is provided by the capacitor and resistor combination 7 and 19 which connects to a tap on either coil through the band selector switch 27. The frequency of oscillation is made relatively independent of variations in tube characteristics when the grid connection is tapped down an appreciable distance from the high-potential end of the coil. The resistors 14 and 15, which carry little current, are connected in series with the grid circuit taps on the coils, and stabilize the operation of the oscillator circuit by suppressing undesirable oscillations. The second coil tap, located near the grounded end of each coil, and connected to the cathode of the oscillator tube through another set of contacts on switch 27, serves to control the amount of feedback in the oscillator circuit. The resistor 21–1 in series with this connection on coil 30 applies additional cathode bias to the grid of the oscillator tube. This cathode bias resistor is bypassed to ground by capacitor 6. The small short-circuited windings shown at the end of each coil in figure 92 are inductive temperature-compensating devices installed inside of the coil forms to compensate for variations in inductance brought about by temperature changes. Resistors 18 and 39 constitute the oscillator tube plate circuit load. (This double resistor arrangement is used in order that the r-f output of the variable frequency oscillator may be modulated when the operation switch 28 is in the MODULATE position. See paragraph 296.) The voltage developed across these load resistors is coupled to detector-converter Tube VT–167 through capacitor 12, or to the antenna through capacitors 12 and 8 in series. Resistor 16–2 is the screen grid dropping resistor, and part 9–1 is the screen grid bypass capacitor to ground.

b. Band Selector Switch. Switch 27 in a double-throw, triple-pole switch with all contacts mounted on ceramic plates. In order to minimize abnormal capacitive effects, all contacts are made as small as possible and are of the self-aligning, self-wiping type. The switch has a heavy detent which accurately locates the rotor plate in either one of its two positions.

c. Corrector Control. Capacitor 2, the CORRECTOR control, with a range of 1.2 micromicrofarads (1.2$\mu\mu$f), enables the operator to control the variable capacitance of the tuned circuits in order to compensate for slight changes in these circuits. (See par. 274f.)

d. Trimming Capacitors. The trimming capacitors are part 3–1 and 3–2. The associated thermal compensator capacitors, part Nos. 4 and 38, reduce changes in circuit capacitance due to temperature changes. Since the coils are compensated for changes in inductance (par. 293a), frequency drifts due to temperature changes are negligible. The trimming capacitors are adjusted at the factory to build up the fixed capacitance of the LOW and HIGH frequency circuits to the exact values called for by the design of the variable tuning capacitor.

Caution: Do not tamper with these trimmer capacitor settings. To do so will throw the meter completely off calibration.

e. Oscillator Function. (1) The variable frequency oscillator circuit is in operation at the CHECK, OPERATE, and MODULATE positions of the operation switch 28. (See fig. 94).

(2) At the CHECK position, the output of oscilator Tube VT–116 (6SJ7) is applied to one of the grids of detector-converter Tube VT–167 (6K8) where it is mixed with the output frequency of the crystal circuit. The result is a frequency equal to the difference of the two, and is used to adjust the frequency of the oscillator by means of the CORRECTOR control.

(3) At the OPERATE position, the variable frequency oscillator is in operation while the crystal oscillator is not. If the antenna is in position, the frequency meter may be used to receive or send any frequency in its range, that is, it may be used as a radio receiver or transmitter.

(4) At the MODULATE position, the variable frequency oscillator is in operation, while the audio amplifier-modulator circuit is changed to operate as an audio-frequency oscillator and modulator in order to modulate the variable frequency oscillator at a frequency of approximately 375 cycles. If the antenna is in position, the frequency meter may be used to send any frequency in its range, modulated at a frequency of 375 cycles, but it cannot be used as a receiver since the audio-frequency amplifier tube has

been converted to an audio-frequency oscillator and the headset has been disconnected by the operation switch.

294. Detector Tube Circuit

It has been stated that the triode section of the Tube VT–167 (6K8) is used in the crystal-oscillator circuit. The remaining hexode section of the tube, of which the No. 1 grid is tied to the control grid of the triode section, is used as a high gain screen grid detector with hexode grid No. 3 grid through the coupling capacitor 8. As a result of these couplings to the control grid, the detector mixes the variable frequency oscillator output with the fundamental and successive harmonics of the crystal oscillator when the operation switch 28 is in the CHECK position, and with the radio transmitter frequency to be measured when the switch is in the OPERATE position. By reference to figures 92 and 93, it can be seen that the antenna post 33 is also coupled to the variable frequency oscillator out-

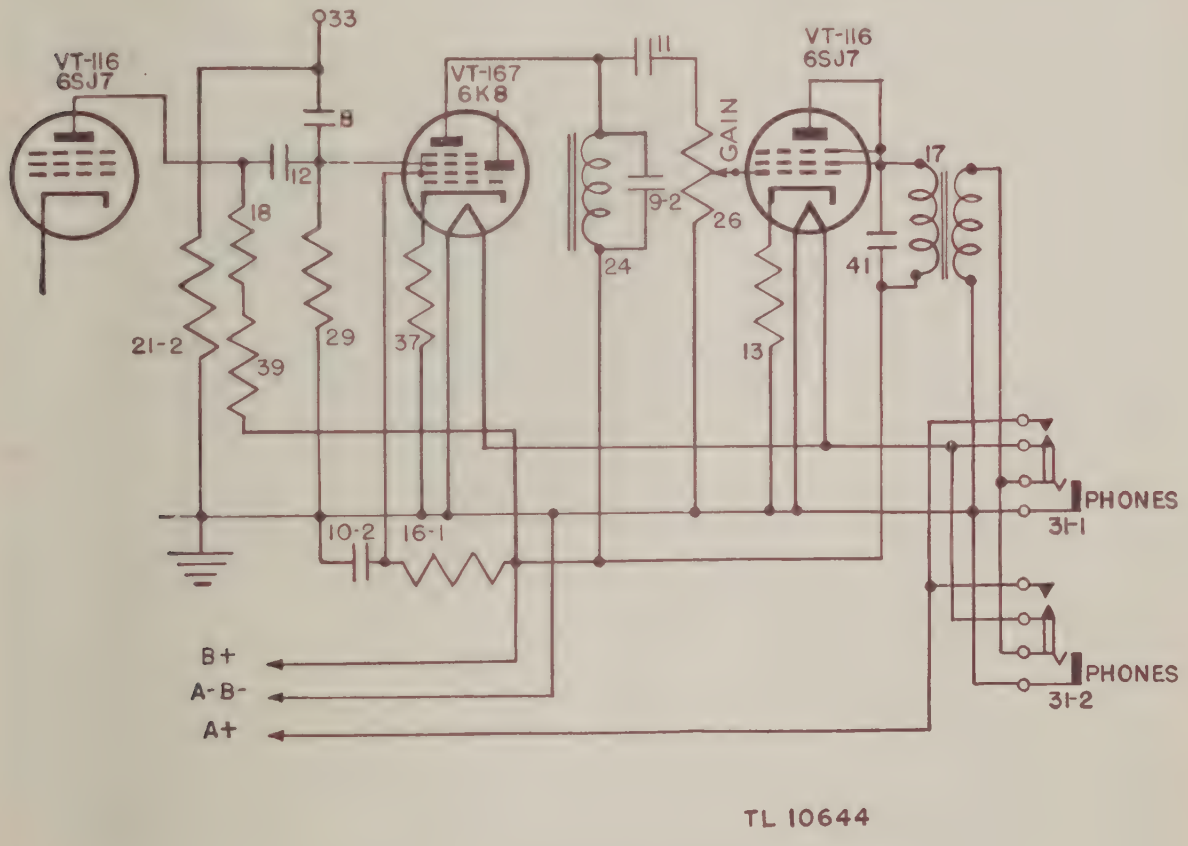


Figure 93. Frequency Meter BC-221-AK, functional diagram, detector and audio-amplifier circuits.

No. 3 acting as the control grid. The joint action of grids Nos. 1 and 3 produces electron coupling of the signals on the two grids. (See fig. 93). Resistor 29 is the detector tube grid leak. Resistor 16–1 supplies voltage to the screen grid of Tube VT–167 (6K8). Capacitor 10–2 bypasses the screen grid to ground. The r-f voltage developed across the load resistors 18 and 39 in the plate output circuit of the variable frequency oscillator is coupled to the No. 3 grid of this detector through a small fixed capacitor 12. The antenna post 33 is also coupled to the put through capacitors 12 and 8 in series. Thus the antenna post serves the dual purpose of a detector input terminal for the measurement of frequencies of external origin and of a variable frequency oscillator output terminal for use in calibrating receivers. When the unit is employed for the latter purpose, a minimum of 2,000 micro-volts of radio frequency energy will be available between the antenna post 33 and the ground post 32 at any frequency within the calibrated range.

295. Audio-Amplifying Circuit (par. 25)

The detector plate works into an audio-frequency choke coil 24, which is bypassed by the capacitor 9–2 to reduce the response to high frequencies. The beat frequency voltages built up across the choke coil are coupled through capacitor 11 and the GAIN control potentiometer 26 to the grid of Tube VT–116 (6SJ7), connected as a triode, through a section of the operation switch 28. The grid of Tube VT-116 returns to ground through a section of the operation switch and the potentiometer 26, and the necessary grid bias voltage is obtained by means of the cathode dropping resistor 13. The plate (tied to the suppressor and screen grids) of Tube VT–116 returns to the positive plate supply voltage through the primary of the audio-output transformer 17. The secondary of the audio-output transformer connects to the PHONES jacks 31–1 and 31–2 and to ground. This is done so that no d-c voltage will be present in the output circuit. The output circuit is designed for the use of the low impedance type Headset HS–30–(&). Under certain conditions the high impedance type Headset P–18 and P–20 might be substituted for the HS–30–(&) but the results obtained will in general be inferior.

296. Audio Oscillator-Modulator Circuit

A functional diagram of the modulator and variable frequency oscillator circuits, together with the connection of the variable frequency oscillator to the detector tube, is shown in figure 92. The audio oscillator-modulator unit provides a source of audio-frequency voltage for modulating the r-f output signal from the variable frequency oscillator. When the operation switch 28 is in the MODULATE position, the circuits are so arranged that energy is fed back to the grid circuit of audio Tube VT–116 from the secondary of the audio-output transformer 17. The primary winding in the plate circuit of the audio tube, coupled to the secondary winding, completes the oscillating circuit. The capacitor 41, across the primary winding, together with the inductance of the primary winding, constitutes the resonant circuit that determines the audio output frequency of approximately 375 cycles. The plate voltage of the audio oscillator-modulator tube is obtained from the plate circuit (junction of resistors 18 and 39) of the variable frequency oscillator tube through series resistor 40. The output of the audio oscillator-modulator is divided by resistors 39 and 40 and fed to the plate of the variable frequency oscillator tube. With this arrangement, audio-frequency voltage variations are introduced into the plate circuit of the variable frequency oscillator tube, causing modulation to take place. Note that the output connections to the PHONES jacks are open with the operation switch in the MODULATE position, and no sound can be heard in the headset.

297. Power Supply Circuit (fig. 94)

All power required for the operation of the meter is introduced through the battery terminal board 36, located at the end of the battery cable. The common negative filament and negative plate battery leads are connected to the middle terminal which is grounded to the chassis. A fabricated wiring harness and a fiber terminal board used in connection with the battery harness are provided for intercell and filament battery to terminal board connections. The operation switch 28 closes both the positive 6-volt supply (A+) and the positive 135-volt supply (B+). The positive 6-volt supply (A+) passes through the auxiliary switches on the PHONES jacks 31–1 and 31–2 before going through the operation switch 28 to the vacuum tube filaments. The circuit is complete only when a headset plug is inserted in one of the jacks. Since the door covering the control panel cannot be closed with a headset plug in place, the *A* and *B* batteries cannot be discharged even though the operation switch is left in an active position when the meter is removed from service.

Section IV. MAINTENANCE

298. General

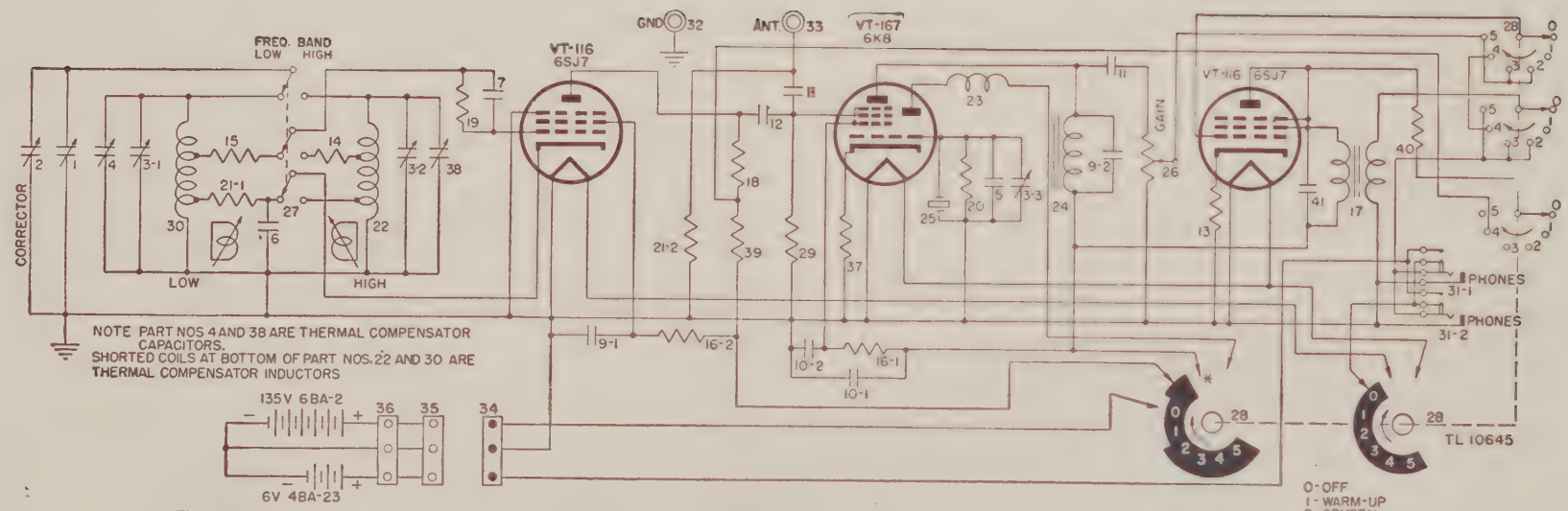
For all details of field maintenance, see paragraphs 26, 27, and 28.

Section V. SUPPLEMENTARY DATA

299. Tabular List of Maintenance Parts for Frequency Meter BC–221–AK

NOTE. Order maintenance parts by stock number, name, and description.

Ref. No. symbol	Signal Corps stock No.	Name of part and description	Quan. per equip	Lowest maint. echelon
	2Z481AK	BAG: BG–81–AK; carrying	1	3d
	2Z551–160	BAG: BG–160–(&)/S; available for amphibious operations	1	Orgn stock
	3A2	BATTERY: BA2; 22.5=v	6	3d
	3A23	BATTERY: BA23; 1.5=v	4	3d
	3E1605–6.5	CORD: CD–605; 6½=ft; 2=cond.; PL–55 at one end; Transformer C–410 at other	1	3d
	3E1874	CORD: CD–874; 6½=ft.; 2=cond.; PL–55 on one end; JB–47 on other end	1	3d
	2B830(&)	HEADSET: HS–30–(&); component HEADSET: HS–30–(&); repair parts	1	Orgn stock
	2B1300	INSERT: M–300	2	Orgn stock
	2Z9019A	STRAP: ST–19–A	1	3d



REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	200 μμf	8	25 μμf	15	1,500 OHM	22	25.84 MICROHY	29	470,000 OHM	36	BATTERY TERM.
2	1.2 μμf	9-1&2	.001 μf	16-1&2	10,000 OHM	23	1.0 MILLIHY	30	7.06 MILLIHY	37	150 OHM
3-1-2&3	12 μμf	10-1&2	.25 μf	17	OUTPUT TRANS	24	150 HENRYS	31-1&2	JACK	38	10 μμf
4	10 μμf	11	.02 μf	18	50,000 OHM	25	CRYSTAL	32	BINDING POST	39	18,000 OHM
5	6.0 μμf	12	50 μμf	19	330,000 OHM	26	0.5 MEGOHM	33	BINDING POST	40	18,000 OHM
6	250 μμf	13	1,000 OHM	20	1 MEGOHM	27	SWITCH	34	POWER PLUGS	41	.002 μf
7	15 μμf	14	27 OHM	21-1&2	5,000 OHM	28	SWITCH	35	POWER JACKS		

Figure 94. Frequency Meter BC–221–AK, schematic diagram.

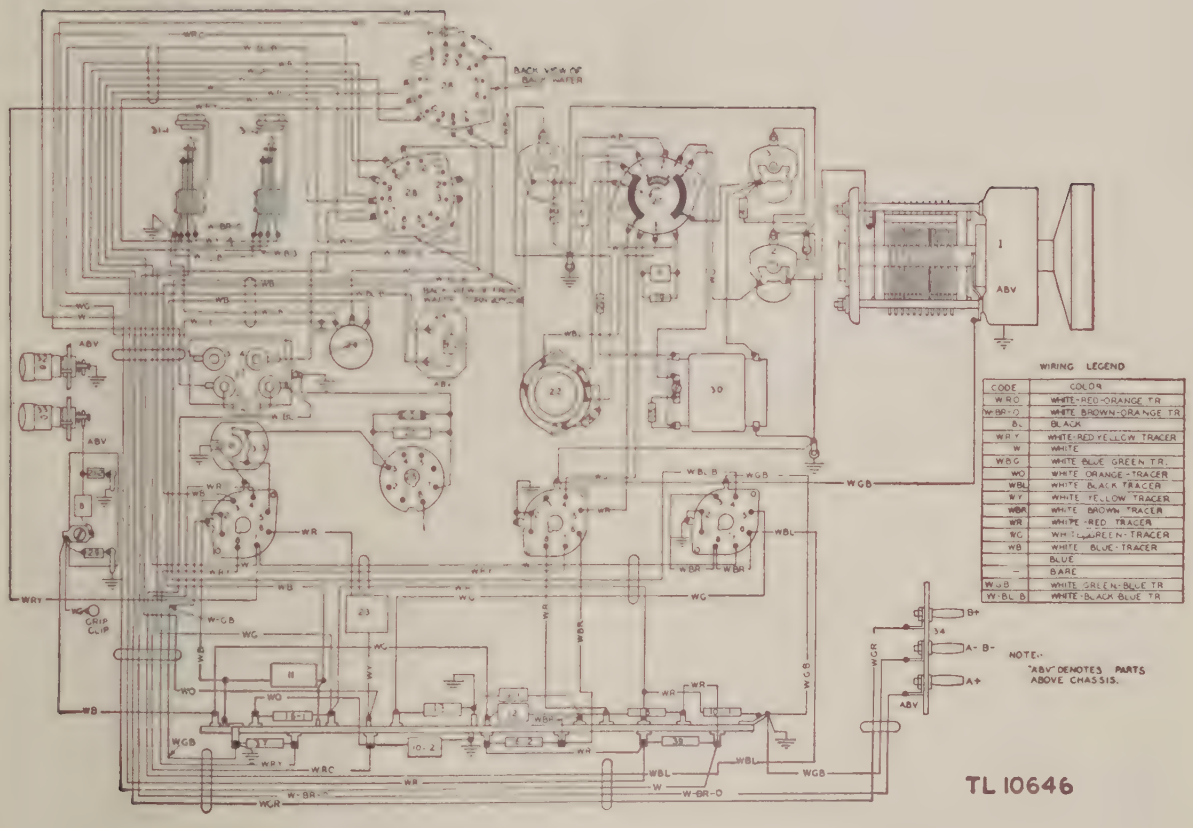


Figure 95. Frequency Meter BC–221–AK, chassis wiring diagram.

CHAPTER 11

FREQUENCY METER SETS SCR–211–AJ AND SCR–211–AL

Section I. DESCRIPTION

300. General

Frequency Meter Set SCR–211–AJ has been manufactured by the Rauland Corporation, and Frequency Meter Set SCR–211–AL has been manufactured by the Zenith Radio Corporation, on several orders. These models are similar to the SCR–211–AK, discussed in the preceding chapter, in that they also contain a modulating unit and a WARM-UP position. In these models, the WARM-UP position is a position of the POWER switch. When the operation switch is at MOD. OSC., the output of the variable frequency oscillator is modulated at a frequency of approximately 400 cycles. This provides a means of calibrating and testing receivers which are not equipped with a c-w oscillator. In the WARM-UP position of the POWER switch, only the filament of variable frequency oscillator Tube VT–116–B (6SJ7Y) is turned on. This eliminates any unnecessary drain on the *A* and *B* batteries during the initial warm-up period. This provision results in a considerable saving in battery life. The two models included in this chapter are electrically alike, with two exceptions: The values of parts 24 and 43 vary, and part 54 was omitted from the SCR–211–AL. These variations are noted where necessary. For further general information see paragraph 2. The symbol (8), as used in this chapter, refers to either the SCR–211–AJ or SCR–221–AL.

301. Components

Each Frequency Meter Set SCR–211–(8) includes the following component units:

Quantity	Article
1	Frequency Meter BC–221–(8) includes:
	1 Crystal Unit DC–9–M or DC–9–P or DC–9–AD (in operating position)[1].
	1 Calibration Book MC–177–(8).
	1 Wrench for Bristo No. 8 set screw (spares compartment).
2	Tubes VT–116–B, type 6SJ7Y (one in use, one spare).
2	Tubes VT–167, type 6K8 (one in use, one spare).
1	Tube VT–116, type 6SJ7 (in operating position)[2].
1	Cord CD–874 for Headset HS–30–(&).
1	Strap ST–19–A.
2	Technical manuals for Frequency Meter Set SCR–211–(8).

[1] Any crystal unit with nomenclature N or higher can be used interchangeably with any frequency meter set with nomenclature N or higher.

[2] On Order No. 36827–Phila–43, a spare Tube VT–116 was furnished with the SCR–211–AJ.

NOTE. A bag is not furnished with the SCR–211–(8). A suitable cover is supplied with the wooden cabinet and is not considered to be a separate component.

302. Additional Equipment Required

The following equipment, not furnished with the orders, is required to complete each Frequency Meter Set SCR–211–(8).

Quantity	Article
1.....	Headset HS–30–(&)*.
6.....	Batteries BA–2.
4.....	Batteries BA–23.

* If Headset HS–30–(&) cannot be obtained, substitute Headset P–18 or P–20.

303. Total Weight

Frequency Meter Set SCR–211–(8), complete and ready for service, weighs approximately 40 pounds. For typical dimensions see figure 27.

304. Power Consumption

All power required for the operation of this equipment is supplied by the batteries listed in paragraph 302. The current drains at the specified voltage limits are as follows:

Filaments: 5.4 to 6.0 volts, 0.86 to 0.91 ampere.
0.30 ampere with POWER switch at WARM-UP.

Plates, etc.: 121.5 to 135.0 volts, 0.016 to 0.18 ampere.

These values are typical for operation with the operation switch at the XTAL CHECK position, under which condition maximum plate current is drawn. Battery life varies greatly depending upon the length of individual periods of operation, the length of time the batteries are allowed to rest between successive periods of operation, and the temperature of the place where the instrument is stored or used. High temperatures and long individual periods of operation will shorten battery life. The WARM-UP position of the POWER switch should be used during warming-up periods or during stand-by periods not exceeding 1 hour, when it is desired to keep the frequency stabilized.

305. Controls (par. 2e)

When the snap latches are released and the front cover lowered, the control panel is exposed. The calibration book is exposed when the inside portion of the front cover is opened. There are seven operating controls (fig. 7):

a. Two PHONES jacks allow for observations by two persons at the same time; for example, student and instructor. A headset must be plugged into one of these jacks before the meter can be set into operation because of the series filament supply switches built into the jacks.

b. When the POWER-OFF WARM UP-ON switch is at OFF, the *A* battery circuit is off and the *B* battery circuit from the meter is grounded; when the switch is at WARM-UP, the *A* battery circuit is connected to the variable frequency oscillator filament only and the *B* circuit is open but not grounded; when the switch is at ON, the *A* battery connects to all three tubes and the *B* battery circuit is completed. Turn the POWER switch to WARM-UP position when warming up the meter for any long period of time. *This will conserve two-thirds of the life of the battery.* When the instrument is not in use, turn the POWER switch to OFF.

c. The GAIN control is a volume control used to adjust the input voltage to the audio-amplifier tube, and in turn the level of sound in the headset.

d. The MOD. OSC–HET. OSC.–XTAL CHK–XTAL ONLY control is the operation switch of the BC–221–(8). In the MOD. OSC. position, the audio-amplifier circuit is converted to an audio-frequency oscillator circuit and in addition, the *B* battery circuit is closed to all tubes with the exception of the crystal oscillator. In the HET. OSC. position, the *B* battery circuit is closed to all tubes with the exception of the crystal oscillator portion of the detector-converter tube and the final stage of the frequency meter acts as an audio amplifier. In the XTAL CHK position, the *B* battery circuit is closed to all tubes including the crystal oscillator and the final stage acts as an audio amplifier. In the XTAL ONLY position, the *B* battery circuit is closed to all tubes with the exception of the variable frequency oscillator. The XTAL CHK position places maximum load on the batteries.

e. The FREQ. BAND LOW-HIGH switch permits the selection of the appropriate band of operation of the variable frequency oscillator as indicated by the frequency being checked or calibrated.

f. The frequency of the variable frequency oscillator is controlled by the setting of the dial labeled "Dial units" which is graduated into 100 divisions. One revolution of the DIAL UNITS dial moves the DIAL HUNDREDS dial one division. (See par. 11.)

g. The CORRECTOR knob controls a small variable capacitor across the variable frequency oscillator tuned circuit and is used to compensate

for small changes in capacity brought about by temperature, humidity, and mechanical changes. It is adjusted at each CRYSTAL CHECK POINT to make the calibration of the instrument as accurate as possible over that part of the scale centered at a given CRYSTAL CHECK POINT and extending halfway to the next higher and next lower CRYSTAL CHECK POINTS.

306. Vacuum Tubes

The vacuum tubes used in the Frequency Meter Set SCR–211–(8) are shown in the following tabulation:

Reference	Function	Signal Corps Type nomenclature	Commercial equivalment	Base
VT–116–B*	Variable frequency oscillator.	VT–116–B*	6SJ7Y*.....	Octal*
VT–167.....	Crystal oscillator and detector.	VT–167	6K8.....	Octal
VT–116.....	Audio–frequency amplifier.	VT–116.....	6SJ7.....	Octal

* Tube VT–116–B is practically the same as Tube VT–116, but has a special electrically low-loss base. In an emergency, a Tube VT–116 can be used in the variable frequency oscillator, but temperature and humidity changes might cause undesirable effects.

Section II.

INSTALLATION AND OPERATION

307. Initial Procedure (par. 7)

Make sure a spare set of tubes is installed in the space provided.

308. Installation of Batteries (pars. 8 and 187b)

309. Antenna (par. 9)

310. Headset (par. 10)

The headset necessary to operate Frequency Meter Set SCR–211–(8) is kept in the compartment at the lower front of the cabinet. (See fig 25.) Headset HS–30–(&) has an impedance of 250 ohms. A headset plug must be inserted into one of the PHONES jacks before the meter will operate.

311. Preparation for Use

a. To start the meter, insert the headset plug into a PHONES jack and turn the POWER switch to the WARM-UP position.

b. After starting the set by the method described above, allow 15 minutes for variable frequency oscillator tube VT–116–B to warm up.

c. In order to test for normal operating conditions, set the operation switch knob at XTAL CHK. While rotating the DIAL UNITS dial, listen in the headset for tones of increasing and decreasing pitch. These different tones are produced by the changing variable oscillator frequency beating with various crystal harmonics. The presence of these tones indicates normal operation.

312. Reading the Dial (par. 11)

313. Calibration Book MC–177–(8) (par. 12)

314. Operating Circuits (par. 13)

The BC–221–(8) contains one principal operating part in addition to the parts described in paragraph 13: The audio oscillator-modulator which generates an audio voltage for modulating the r-f signal output of the variable frequency oscillator.

315. Zero Beat Detection (par. 14)

316. Correction in Calibration

Turn the POWER switch to the ON position, the FREQ. BAND switch to the LOW or HIGH position as required, and the operation switch to the XTAL CHK position; then follow the procedure in paragraph 15. After completing this procedure, turn the operation switch to the HET. OSC. position and proceed with any measurements.

317. Crystal Check Points (par. 16)

318. Frequency Measurements (par. 17)

The proper position of the operation switch is HET. OSC. for making frequency measurements as described in paragraph 17. The modulation feature, provided in Frequency Meter BC–221–(8), makes possible the following additional measurements:

a. To Measure the Frequency to Which a Receiver Is Tuned, When Receiver Is Not Equipped With a C-w Oscillator. (1) Put the meter in operation as instructed. (See par. 311.)

(2) Place the antenna of the frequency meter near and parallel to the antenna of the receiver.

(3) Turn the operation switch to MOD. OSC.

(4) Vary the DIAL UNITS dial of the frequency meter until a 400-cycle note is heard in the speaker or headset of the receiver.

(5) Determine the frequency at this dial setting from the calibration book and calibrate the meter at the nearest CRYSTAL CHECK POINT.

(6) Reset the operation switch on the frequency meter to MOD. OSC. and adjust the main tuning dial until the 400-cycle tone is heard again in the speaker of the receiver.

(7) If the signal tunes broadly; that is, if it is audible over several divisions of the DIAL UNITS dial of the frequency meter, decrease the coupling between the frequency meter and the receiver by moving the frequency meter antenna farther away from the antenna of the receiver. As the coupling is decreased, the signal will tune more sharply and will be audible over a very small portion of the DIAL UNITS dial. The sharper the tuning, the greater will be the accuracy of the measurement.

(8) Adjust the DIAL UNITS dial for maximum signal in the speaker or headset of the receiver and lock the dial by turning the dial lock to the right.

(9) Observe the dial setting and determine the frequency corresponding to this setting from the calibration book. If the exact frequency is not given, determine it by interpolation as instructed. (See par. 12e.)

b. To Tune Receiver, Not Equipped with C-w Oscillator, To a Desired Frequency: (1) Put the meter in operation as instructed. (See par. 311.)

(2) Place the antenna of the frequency meter near and parallel to the antenna of the receiver.

(3) Turn the operation switch to XTAL CHK.

(4) Set the FREQ. BAND switch to the proper band, either LOW or HIGH.

(5) Select the proper dial setting for the desired frequency from the calibration book; then set the DIAL UNITS dial of the meter to the CRYSTAL CHECK POINT nearest this frequency.

(6) Correct the frequency meter by adjusting the CORRECTOR control until zero beat is obtained.

(7) Turn the operation switch to MOD. OSC.

(8) Set the DIAL UNITS dial of the frequency meter to the desired frequency point. Lock the dial by turning the dial lock to the right.

(9) Rotate the receiving tuning dial until the signal from the frequency meter is picked up, as indicated by a 400-cycle note in the speaker or headset.

(10) For greatest accuracy, the coupling between the receiver and the frequency meter should be adjusted so that the signal tunes sharply on the receiver. At this point, the receiver will be tuned to within a few cycles of the frequency being generated by the frequency meter.

c. Miscellaneous Measurements. Other uses of the MOD. OSC. position of the frequency meter may occur to the operator. For example, the frequency meter may be used to perform an emergency alignment on a receiver when a regular signal generator is not available. No attenuator is included in the frequency meter, however. Consequently the only means of controlling the input signal to the receiver that is being aligned is to vary the coupling between the frequency meter and the antenna attached to the receiver. If proper allowances are made for this fact, the frequency meter may be used very conveniently as a signal generator, and the output frequencies obtained will be extremely accurate, much more so than can be expected from the average signal generator.

319. Precautions During Operation (par. 18)

320. Adjustments for Field Upkeep (par. 19)

Section III. FUNCTIONING OF PARTS

321. General

The BC–221–(8) is very similar to the meters described in chapter 6 of this manual with regard to the operation of the variable frequency oscillator, the detector and crystal oscillator, and audio-amplifier circuits. A four-position operation switch is employed, however, instead of the three-position switch which was used on earlier models. This four-position switch provides control of one additional circuit, the modulator circuit. The POWER switch has three positions instead of the two positions formerly used. At the third position of the POWER switch, WARM-UP, only the filament of variable frequency oscillator Tube VT–116–B (6SJ7Y) draws current. (See figs. 99 and 100.)

322. Circuit Components (par. 21)

The circuit of Frequency Meter BC–221–(8) contains one component part in addition to those given in paragraph 21: the audio oscillator-modulator circuit, which generates an audio-frequency voltage for the modulation of the r-f output of the meter.

323. Crystal Circuit

The crystal circuit uses the triode section of Tube VT–167 (6K8). (See fig. 96.) The oscillator operates at the fixed frequency of 1,000 kc when the operation switch 28 is placed in the XTAL CHK or XTAL ONLY position. The operation switch controls the crystal oscillator by opening or closing it plate voltage circuit. The oscillator circuit is designed to generate

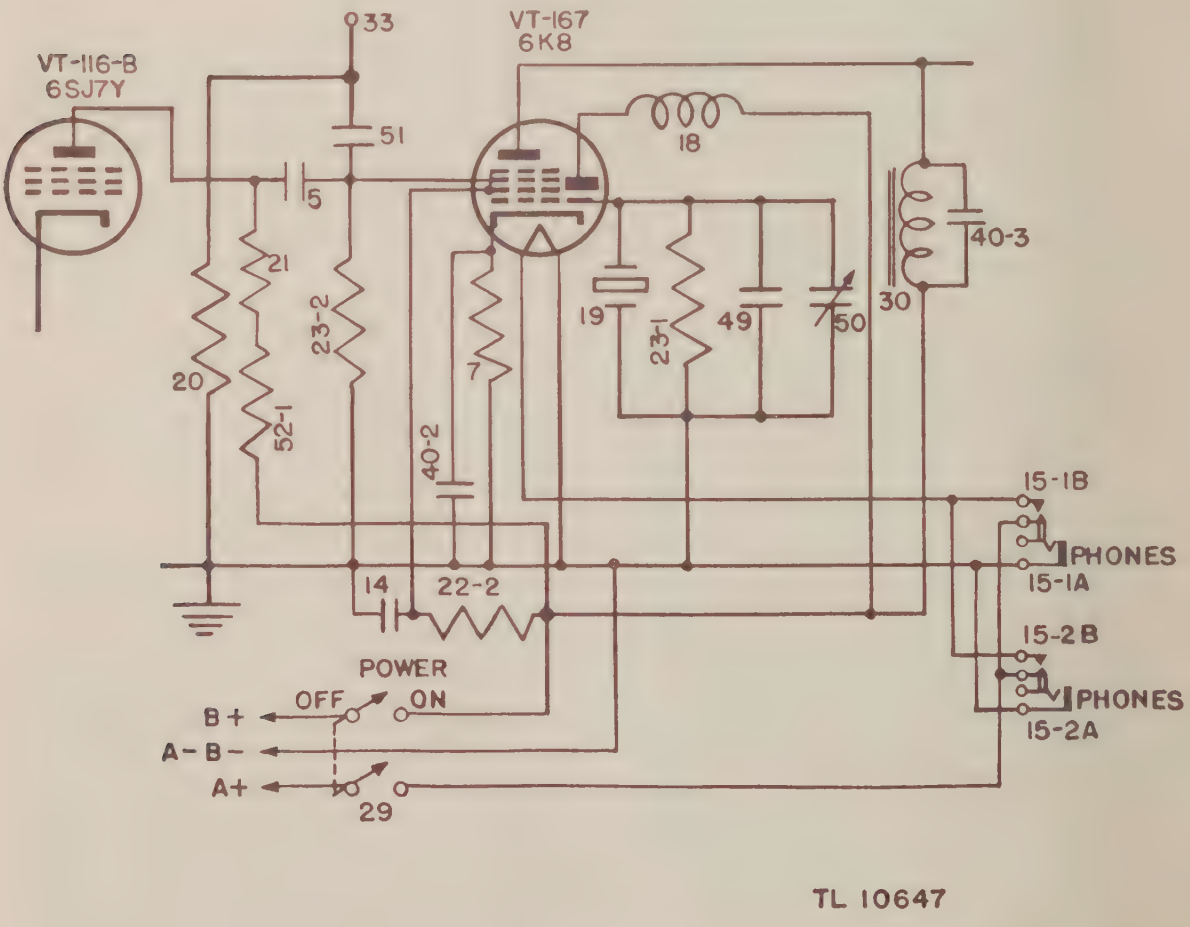


Figure 96. Frequency Meter BC2–21–(8), functional diagram, crystal-oscillator circuit.

considerable harmonic energy so that it can be used to calibrate the variable frequency oscillator, at several points over its entire range, as well as to supply whole multiples of 1,000 kc for the calibration of receivers and similar equipment. The necessary plate circuit impedance is built up across the choke coil 18. The variable capacitor 50 is connected across the crystal for the purpose of adjusting the frequency of the crystal to a closer point than can be economically obtained by grinding alone. When the frequency meters are adjusted during manufacture, the variable capacitor is set up to produce a frequency of 1,000 kc ± 5 cycles at 20° centigrade. The fixed capacitor 49, shunted across the crystal, minimizes any change in fundamental frequency due to small changes in the crystal capacitance. Resistor 23–1 is the oscillator grid leak and works in conjunction with the tube cathode resistor 7 which is bypassed to ground by capacitor 40–2. Further reference to figure 96 shows that the output of the crystal oscillator is electron coupled to the antenna through the No. 3 grid of the hexode section of Tube VT–167 and capacitor 51. For further details on the crystal oscillator, see paragraph 22.

324. Variable Frequency Oscillator Circuit (par. 23)

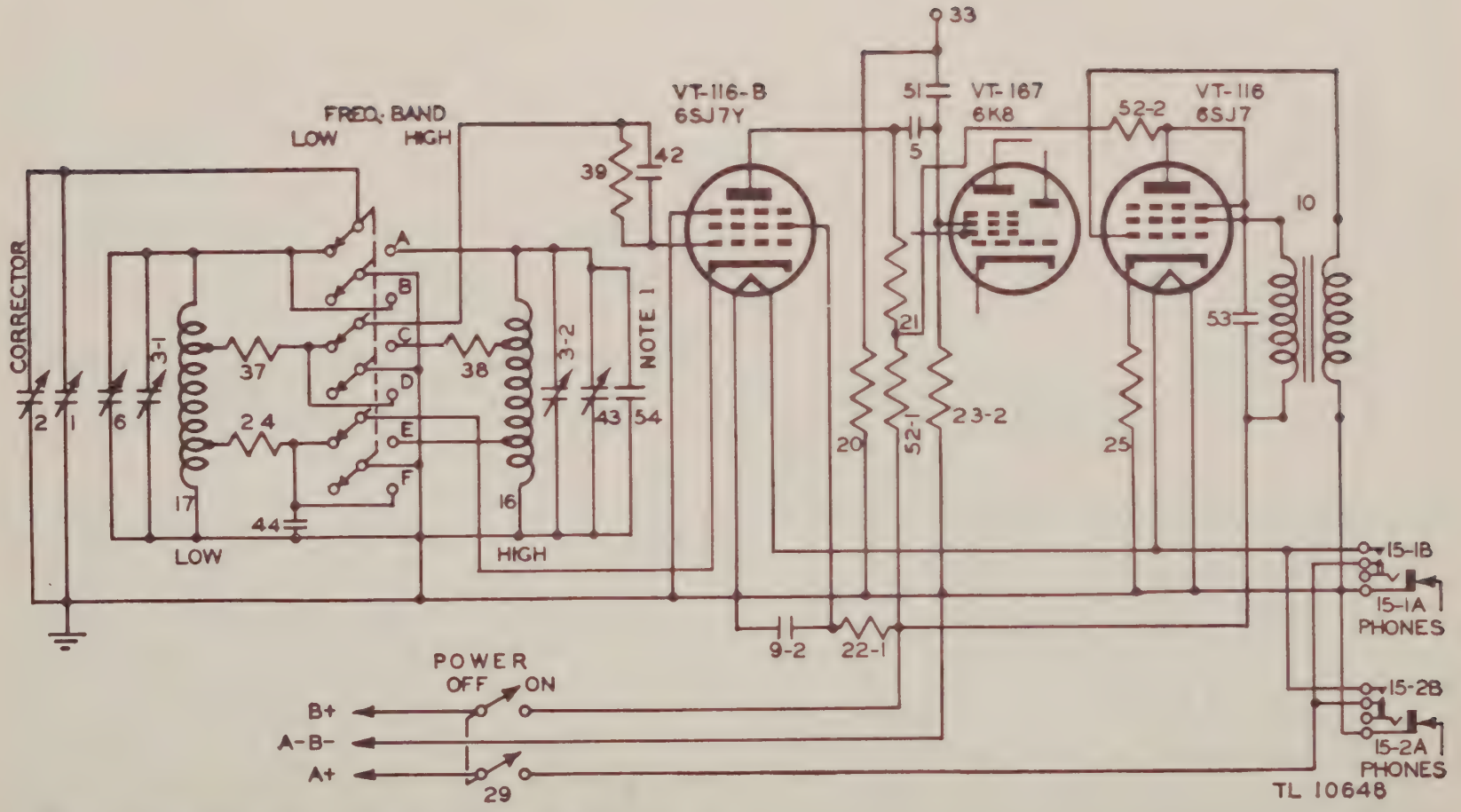
Tube VT–116–B (6SJ7Y) is used in an electron coupled circuit as the variable frequency oscillator. (See fig. 97.)

a. Coils. The two inductors 16 and 17, in the tuned circuits, are wound upon ceramic forms and coated with a special wax to eliminate the influence of changing atmospheric conditions on the stability of the meter. The active terminals of these coils are connected across the terminals of the main tuning capacitor 1 by means of the band selector (FREQ. BAND LOW-HIGH) switch 27. Each coil and the tuning capacitor, together with other capacitors mentioned below, constitute the resonant circuit that determines the output frequency. The correct operating bias on the control grid of the oscillator tube is provided by the capacitor and resistor combination 42 and 39 which connects to the grid tap on either coil through the band selector switch 27. The frequency of oscillation is made relatively independent of variations in tube characteristics when the grid connection is tapped down an appreciable distance from the high-potential end of the coil. The resistors 37 and 38, which carry little current are connected in series with the grid circuit taps on the coils, and stabilize the operation of the oscillator circuit by suppressing undesirable oscillations. The second coil tap, located near the grounded end of each coil, and connected to the cathode of the oscillator tube by another set of contacts on switch 27, serves to control the amount of feedback in the oscillator circuit. The resistor 24 in series with this connection on the LOW coil 17 applies additional bias to the grid of the oscillator tube when the band selector switch is in the LOW position. This cathode bias resistor is bypassed to ground by capacitor 44. Resistors 21 and 52–1 constitute the oscillator tube plate circuit load. This double resistor arrangement is used in order that the r-f output of the variable frequency oscillator may be modulated when the operation switch 28 is in the MOD. OSC. position. (See par. 327.) The voltage developed across these load resistors is coupled to detector-converter Tube VT–167 through capacitor 5, or to the antenna through capacitors 5 and 51 in series. Resistor 22–1 is the screen grid dropping resistor, and part 9–2 is the screen grid bypass capacitor to ground.

b. Band Selector Switch. The band selector switch 27 is a six-pole double-throw switch with all contacts mounted on ceramic plates. In order to minimize abnormal capacitive effects, all contacts are made as small as possible and are of the self-aligning, self-wiping type. The switch has a heavy detent which accurately locates the rotor plate in either one of its two positions.

c. CORRECTOR Control. Capacitor 2, the CORRECTOR control, with a range of 1.5 micromicrofarads (1.5$\mu\mu$f), enables the operator to control the variable capacitance of the tuned circuits in order to compensate for slight changes in the circuit. (See par. 305g.)

d. Trimming Capacitors. The trimming capacitors are parts 3–1 and 3–2. Part 6 and 43, in parallel with these trimming capacitors, are temperature compensating capacitors which prevent frequency drifts due to temperature changes. The additional capacitor 54 across the HIGH frequency coil 16, in the BC–221–AJ only, provides an additional fixed capacitance in this circuit. The trimming capacitors are adjusted at the factory to build up the fixed capacitance of the LOW and HIGH frequency circuits to the exact values called for by design of the variable tuning capacitor.



NOTE 1: PART NO. 54 IS OMITTED FROM THE BC-221-AL

Figure 97. Frequency Meter BC-221 (8), functional diagram, variable frequency oscillator and audio-modulator circuits.

Caution: Do not tamper with these trimmer capacitor settings. To do so will throw the meter completely off calibration.

e. Oscillator Function. (1) The variable frequency oscillator circuit is in operation whenever the POWER switch 29 is in the ON position, the operation switch 28 is in the MOD. OSC., HET. OSC., or XTAL CHK position, and a headset is plugged into a PHONES jack. (See figs. 99 and 100.)

(2) At the XTAL CHK position of the operation switch 28, the output of oscillator Tube VT–116–B (6SJ7Y) is applied to the No. 3 grid of the hexode section of detector-converter Tube VT–167 (6K8) where it is mixed with the output frequency of the crystal circuit. The result is a frequency equal to the difference of the two, and is used to adjust the frequency of the oscillator by means of the CORRECTOR control.

(3) At the HET. OSC. position of the operation switch 28, the variable frequency oscillator is in operation while the crystal oscillator is not. If the antenna is in position, the frequency meter may be used to receive or send any frequency in its range; that is, it may be used as a radio receiver or transmitter.

(4) At the MOD. OSC. position, the variable frequency oscillator is in operation, while the audio amplifier-modulator circuit is changed to operate as an audio-frequency oscillator and modulator in order to modulate the variable frequency oscillator at a frequency of approximately 400 cycles. If the antenna is in position, the frequency meter may be used to send any frequency in its range modulated at the frequency of 400 cycles, but it cannot be used as a receiver since the audio-frequency amplifier tube has been converted to an audio-frequency oscillator and the headset has been disconnected by the operation switch.

325. Detector Tube Circuit

It has been stated that the triode section of Tube VT–167 (6K8) is used in the crystal-oscillator circuit. The remaining hexode section of the tube, of which the No. 1 grid is tied to the control grid of the triode section, is used as a high gain screen grid detector with hexode grid No. 3 acting as the control grid. The joint action of grids No. 1 and 3 produces electron coupling of the signals on the two grids. (See fig. 98.) Resistor 22–2 supplies voltage to the screen grid of Tube VT–167 (6K8). Capacitor 14 bypasses the screen grid to ground. Note that the antenna

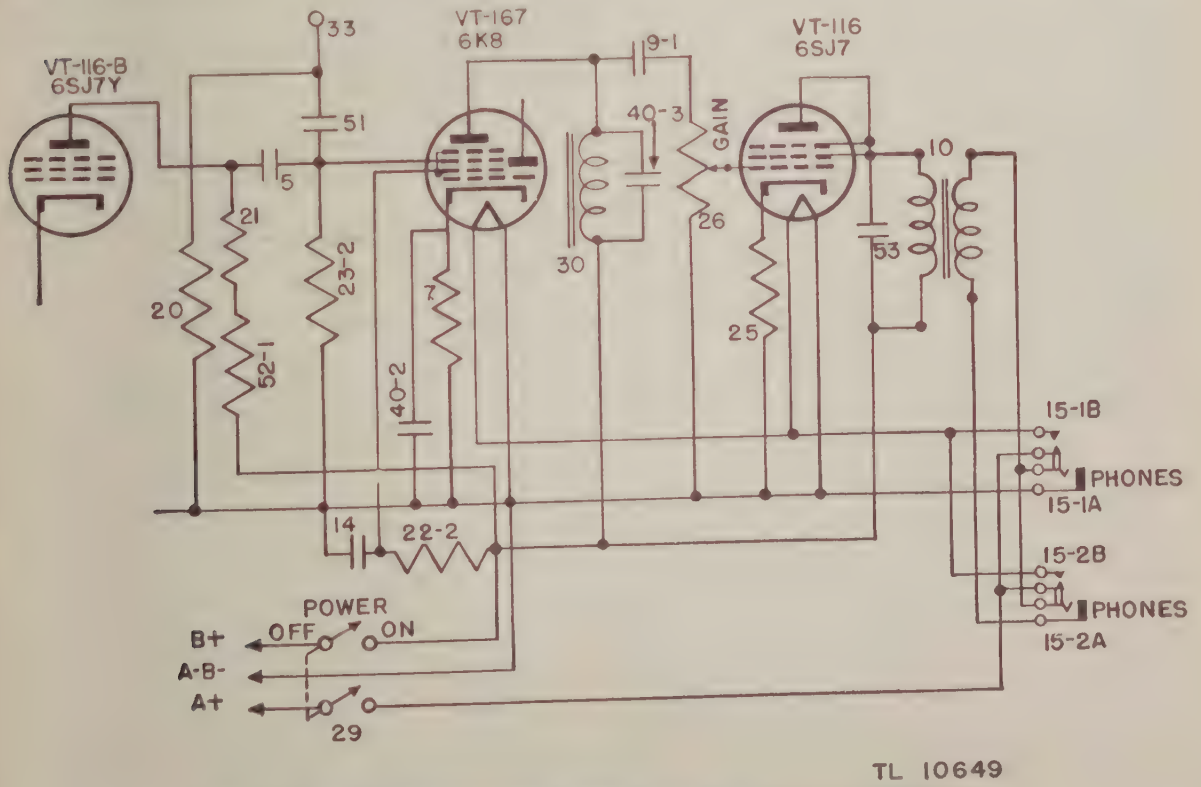


Figure 98. Frequency Meter BC–221–(8), functional diagram, detector and audio-amplifier circuits.

post 33 is connected to ground through the resistor 20. The r-f voltage developed across the load resistors 21 and 52–1 in the plate output circuit of the variable frequency oscillator is coupled to the No. 3 grid of this detector through a small fixed capacitor 5. The antenna post 33 is also coupled to the No. 3 grid through the coupling capacitor 51. As a result of these couplings to the control grid the detector mixes the variable frequency oscillator output, with the fundamental and successive harmonics of the crystal oscillator, when the operation switch is in the XTAL CHK position, and with the radio transmitter frequency to be measured, when the switch is in the HET. OSC. position. By reference to figure 98 it can be seen that the antenna post 33 is also coupled to the variable frequency oscillator output through capacitors 51 and 5, in series. Thus, the antenna connection serves the dual purpose of a detector input terminal for the measurement of frequencies of external origin and of a variable frequency oscillator output terminal for use in calibrating receivers. When the unit is employed for the latter purpose, a minimum of 2,000 microvolts of radio frequency energy will be available between the antenna post 33 and the ground post 32 at any frequency within the calibrated range.

326. Audio-Amplifying Circuit (par. 25)

The detector plate works into an audio-frequency choke coil 30, which is bypassed by the capacitor 40–3 to reduce the response to high frequencies. The beat frequency voltages built up across the choke coil are coupled through capacitor 9–1 and the GAIN control potentiometer 26 to the grid of Tube VT–116 (6SJ7), connected as a triode through a section of the operation switch 28. The grid of Tube VT–116 returns to ground through a section of the operation switch 28 and the potentiometer 26, and the necessary grid bias voltage is obtained by means of the cathode dropping resistor 25. The plate (tied to the suppressor and screen grids) of Tube VT–116 returns to the positive plate supply voltage through the primary of the audio-output transformer 10. The secondary of the audio-output transformer connects to the PHONES jacks 15–1*a* and 15–2*a* and to ground. This is done so that no d-c voltage will be present in the output circuit. The output circuit is designed for the use of the low impedance type Headset HS–30–(&). Under certain conditions the high impedance type Headset P–18 or P–20 can be substituted for the HS–30–(&) but the results obtained will in general be inferior.

327. Audio Oscillator-Modulator Circuit

A functional diagram of the modulator and variable frequency ocillator circuits, together with the connection of the variable frequency oscillator to the detector tube, is shown in figure 97. The audio oscillator-modulator unit provides a source of audio-frequency voltage for modulating the r-f output signal from the variable frequency oscillator. When the operation switch 28 is in the MOD. OSC. position, the circuits are so arranged that energy is fed back to the grid circuit of the VT–116 audio tube from the secondary of the audio-output transformer 10. The primary winding in the plate circuit of the audio tube, coupled to the secondary winding, completes the oscillating circuit. The capacitor 53 across the primary winding, together with the inductance of the primary winding, constitutes the resonant circuit that determines the audio-output frequency of approximately 400 cycles. The plate voltage of the audio oscillator-modulator tube is obtained from the plate circuit (junction of resistors 21 and 52–1) of the variable frequency oscillator tube through series resistor 52–2. The output of the audio oscillator-modulator is divided by resistors 52–1 and 52–2 and is fed to the plate of the variable frequency oscillator tube. With this arrangement, audio-frequency voltage variations are introduced into the plate circuit of the variable frequency oscillator tube, causing modulation to take place. Note that the output connections to the PHONES jacks are open with the operation switch in the MOD. OSC position and no sound can be heard in the headset.

328. Power Supply Circuit (figs. 99 and 100)

All power required for the operation of the meter is introduced through the battery terminal board 36, located at the end of the battery cable. The common negative plate battery leads are connected to the middle terminal which is grounded to the chassis. A fabricated wiring harness and a fiber terminal board used in connection with the battery harness are provided for intercell and filament battery to terminal board connection. The positive 6-volt supply (A+) passes through the auxiliary switches on the PHONES jacks 15–1*b* and 15–2*b* before going through the POWER switch 29 to the vacuum tube filaments. The circuit is complete only when a headset plug is inserted in one of the jacks. The positive 135-volt supply (B+)

circuit is closed to the tubes of the meter only when the POWER switch is in the ON position. Since the door covering the control panel cannot be closed with a headset plug in place, the *A* and *B* batteries cannot be discharged even though the POWER switch is left in an active position when the meter is removed from service.

Section IV. MAINTENANCE

329. General

For all details of field maintenance, see paragraphs 26, 27, and 28.

Section V. SUPPLEMENTARY DATA

330. Tabular List of Maintenance Parts

a. Frequency Meter BC-221-AJ.

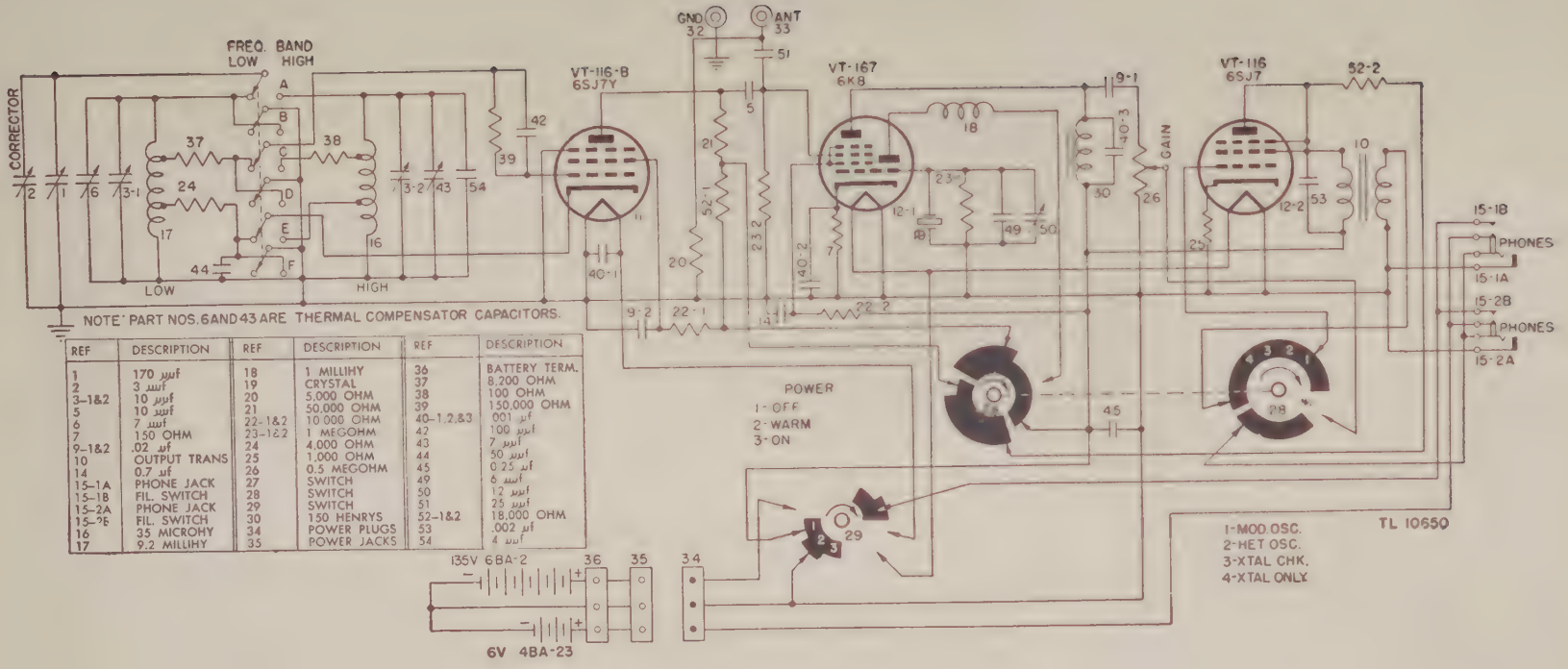
Note. Order maintenance parts by stock number, name, and description.

Ref. No. symbol	Signal Corps stock No.	Name of part and description	Quan. per equip.	Lowest maint echelon
83	3A2	BATTERY: BA–2; 22.5=v	6	3d
84	3A23	BATTERY: BA–23; 1.5=v	4	3d
	2Z481AJ	BAG: BG–81–AJ; carrying	1	3d
	2Z551–160	BAG: BG–160–(&)/S; available for amphibious operations	1	Orgn stock
	3E1605–6.5	CORD: CD–605; 6½=ft; 2=cond.; PL–55 at one end; Transformer C–410 at other	1	3d
	3E1874	CORD: CD–874; 6½=ft.; 2=cond.; PL–55 on one end; JB–47 on other end	1	3d
	2B830(&)	HEADSET: HS–30–(&); component HEADSET: HS–30–(&); repair parts	1	Orgn stock
	2B1300	INSERT: M–300	2	Orgn stock
	2Z9019A	STRAP: ST–19–A	1	3d

b. Frequency Meter BC-221-AL.

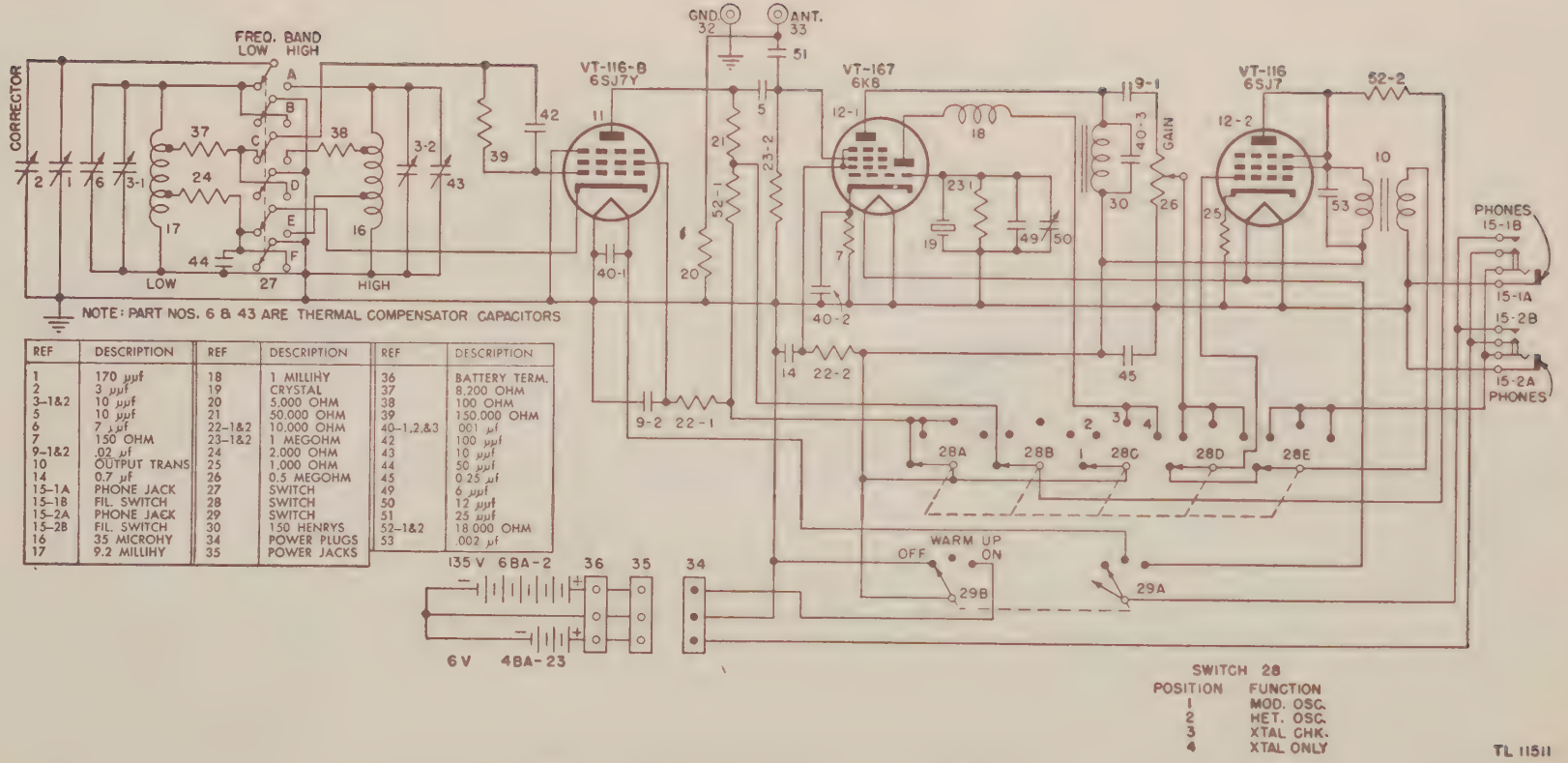
Note. Order maintenance parts by stock number, name, and description.

Ref. No. symbol	Signal Corps stock No.	Name of parts and description	Quan. per equip.	Lowest maint echelon
	2Z481AL	BAG: BG–81–AL; carrying	1	3d
	2Z551–60	BAG: BG–160–(&)/S; available for amphibious operations	1	Orgn stock
	3A2	BATTERY: BA–2; 22.5=v	6	3d
	3A23	BATTERY: BA–23; 1.5=v	4	3d
	3E1605–6.5	CORD: CD–605; 6½=ft; 2=cond.; PL–55 at one end; Transformer C–410 at other	1	3d
	3E1874	CORD: CD 874; 6½-ft; 2-cond.; PL 55 on one end; JB–47 on other end	1	3d
	2B830(&)	HEADSET: HS–30–(&); component HEADSET: HS–30–(&); repair parts	1	Orgn stock
	2B1300	INSERT: M–300	2	Orgn stock
	2Z9019A	STRAP: ST–19–A	1	3d



REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	170 μμf	18	1 MILLIHY	36	BATTERY TERM.
2	3 μμf	19	CRYSTAL	37	8,200 OHM
3-1&2	10 μμf	20	5,000 OHM	38	100 OHM
5	10 μμf	21	50,000 OHM	39	150,000 OHM
6	7 μμf	22-1&2	10 000 OHM	40-1,2,&3	.001 μf
7	150 OHM	23-1&2	1 MEGOHM	42	100 μμf
9-1&2	.02 μf	24	4,000 OHM	43	7 μμf
10	OUTPUT TRANS	25	1,000 OHM	44	50 μμf
14	0.7 μf	26	0.5 MEGOHM	45	0.25 μf
15-1A	PHONE JACK	27	SWITCH	49	6 μμf
15-1B	FIL. SWITCH	28	SWITCH	50	12 μμf
15-2A	PHONE JACK	29	SWITCH	51	25 μμf
15-2B	FIL. SWITCH	30	150 HENRYS	52-1&2	18,000 OHM
16	35 MICROHY	34	POWER PLUGS	53	.002 μf
17	9.2 MILLIHY	35	POWER JACKS	54	4 μμf

Figure 99. Frequency Meter BC-221-AJ, schematic diagram.



REF	DESCRIPTION	REF	DESCRIPTION	REF	DESCRIPTION
1	170 μμf	18	1 MILLIHY	36	BATTERY TERM.
2	3 μμf	19	CRYSTAL	37	8,200 OHM
3-1&2	10 μμf	20	5,000 OHM	38	100 OHM
5	10 μμf	21	50,000 OHM	39	150,000 OHM
6	7 μμf	22-1&2	10,000 OHM	40-1,2,&3	.001 μf
7	150 OHM	23-1&2	1 MEGOHM	42	100 μμf
9-1&2	.02 μf	24	2,000 OHM	43	10 μμf
10	OUTPUT TRANS	25	1,000 OHM	44	50 μμf
14	0.7 μf	26	0.5 MEGOHM	45	0.25 μf
15-1A	PHONE JACK	27	SWITCH	49	6 μμf
15-1B	FIL. SWITCH	28	SWITCH	50	12 μμf
15-2A	PHONE JACK	29	SWITCH	51	25 μμf
15-2B	FIL. SWITCH	30	150 HENRYS	52-1&2	18,000 OHM
16	35 MICROHY	34	POWER PLUGS	53	.002 μf
17	9.2 MILLIHY	35	POWER JACKS		

Figure 100. Frequency Meter BC-221-AL, schematic diagram.

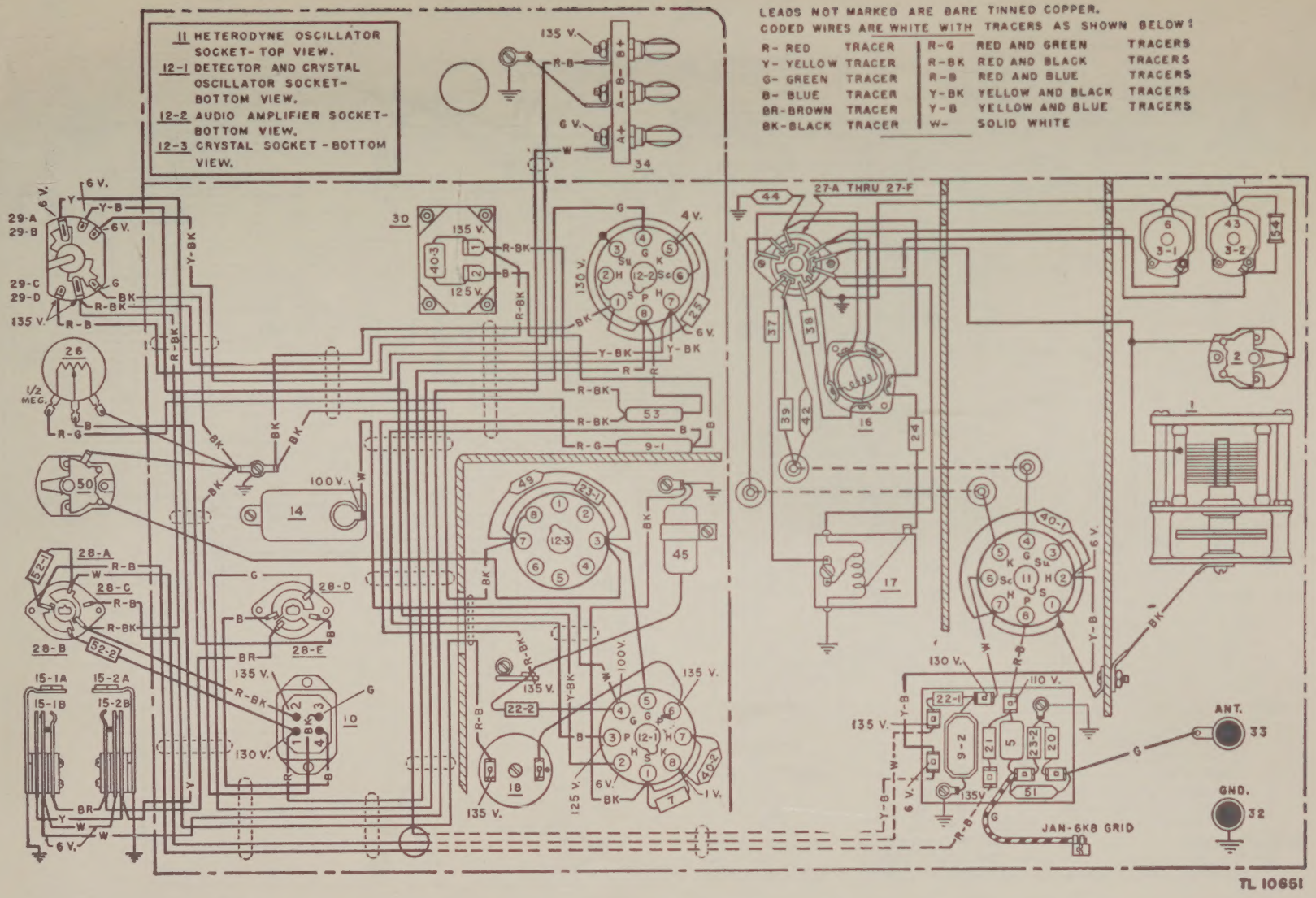

11 HETERODYNE OSCILLATOR SOCKET- TOP VIEW.
12-1 DETECTOR AND CRYSTAL OSCILLATOR SOCKET- BOTTOM VIEW.
12-2 AUDIO AMPLIFIER SOCKET- BOTTOM VIEW.
12-3 CRYSTAL SOCKET - BOTTOM VIEW.
LEADS NOT MARKED ARE BARE TINNED COPPER.
CODED WIRES ARE WHITE WITH TRACERS AS SHOWN BELOW:
R- RED TRACER
Y- YELLOW TRACER
G- GREEN TRACER
B- BLUE TRACER
BR-BROWN TRACER
BK-BLACK TRACER
R-G RED AND GREEN TRACERS
R-BK RED AND BLACK TRACERS
R-B RED AND BLUE TRACERS
Y-BK YELLOW AND BLACK TRACERS
Y-B YELLOW AND BLUE TRACERS
W- SOLID WHITE
27-A THRU 27-F
ANT.
GND.
JAN-6K8 GRID
TL 10651

Figure 101. Frequency Meter BC–221–AJ, chassis wiring diagram.

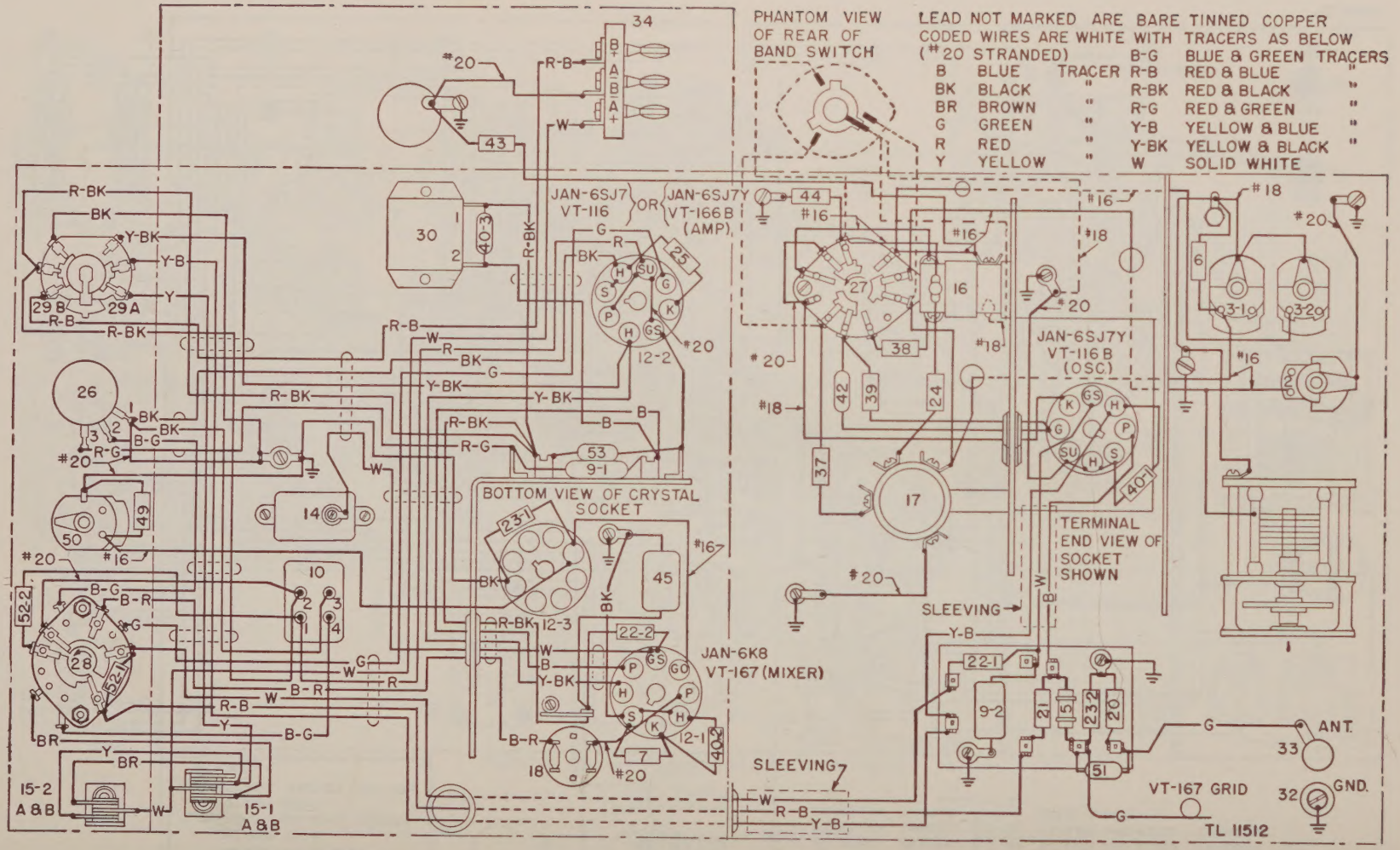


Figure 102. Frequency Meter BC–221–AL, chassis wiring diagram.

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